Protection and Management of the Central American Dome

An oceanic oasis for marine conservation and sustainable fisheries

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Executive Summary

The Central American Dome is a distinct and highly productive biological habitat in the northeastern tropical Pacific, created through an interaction between wind and currents. Here, plankton biomass is higher than in surrounding tropical waters, providing a source of food for squid, commercially important tunas, as well as other marine mammals such as dolphins and whales. Endangered blue whales migrate south from Baja California to the Dome area during the winter to feed, breed, calve and raise calves, and some are found in the area year-round. Critically endangered leatherback turtles leave their nesting beaches in Central America and Mexico and migrate through the Dome area while young hatchlings are transported to the Dome by coastal eddies. It is not surprising that the Central American Dome is considered by scientists a critical habitat to the survival of at least two highly endangered species: the blue whale and the leatherback turtle.

The Central American Dome also provides goods and services to countries in the region, as well as globally. It is considered to be a major sink for atmospheric carbon dioxide, and important for maintenance of the Earth's climate. The Dome region is a major fisheries ground, where commercial fishing boats capture thousands of tons of squid and tuna that provide income and food for countries regionally and internationally. Tourism revenue in nearby coastal areas is linked to turtle and whale populations dependent on the Dome productivity.

The region, while remote, is threatened by many factors. The intensification of commercial shipping increases the collision risk with whales and turtles. Noise disturbance from shipping may also impact hearing and communication of marine species, causing behavioural changes and habitat displacement. Increases in fishing effort in the area will jeopardize the fisheries themselves, eroding the economic basis of a highly productive industry and endangering critical species such as leatherback turtles caught as by-catch. Finally, climate change may threaten the Dome either directly, through changes in oceanographic features and productivity, or by impacting the ranges and migrations of species that utilize the area.

Addressing these threats will require both regional cooperation and international consensus and actions to directly target particular threats. This document is a contribution to the process leading to international recognition, management and protection of the Central American Dome.

Introduction

Biological hot spots in the ocean are often created by physical processes and have distinct oceanographic signatures. Marine predators, including large pelagic fish, marine mammals and seabirds, aggregate together with prey organisms at ocean fronts, eddies, and other physical features (Palacios et al, 2006). These areas are also frequented by commercial and recreational fishing vessels. One such hot spot occurs in the northeastern tropical Pacific at the Central American Dome.

With a mean position near 9°N, 90°W, the Dome is a highly productive area, which varies in size and position throughout the year. The area is heavily exploited by highly migratory marine predators such as tuna, dolphins, and cetaceans, and in particular endangered blue whales (Fiedler, 2002, Palacios, et al 2006). It is also part of the migratory corridor of a population of endangered leatherback turtles nesting in Costa Rica (Shillinger et al., 2008, Shillinger et al., 2011).

Because of its high productivity, importance for migratory and endangered species, as well as uniqueness in the world ocean, the Central American Dome was adopted as an area meeting the Convention on Biological Diversity (CBD) criteria for Ecologically or Biologically Significant Areas (EBSAs) by the Eastern Tropical and Temperate Pacific Regional Workshop to Facilitate the Description of EBSAs (Galápagos Islands, Ecuador, 28 to 31 August 2012). To gain official EBSA status, the Central American Dome will need to be considered and adopted by all Parties to the Convention on Biological Diversity during its meetings in the upcoming years.

The CBD EBSA nomination can be viewed as a first step in a longer process to seek international recognition for the importance and ecological significance of the Central American Dome, and to improve its management and protection. The Central American Governments, MarViva, Marine Conservation Institute, Mission Blue, IUCN, the Whale and Dolphin Conservation Society, the International Committee on Marine Mammal Protected Areas and the IUCN Marine Mammal Protected Area Task Force have joined together in an effort to build an international partnership to ensure that this important ocean area will be able to continue to function as habitat for endangered and economically important species, and to deliver ecosystem goods and services for future generations.

In order to deliver on these aspirations, there is a need for a robust scientific case, which, together with supporting evidence, demonstrates the ecological importance and values of the Central American Dome, and provides justification for why improved protection and management are both necessary and urgent.

This summary science and evidence case provides the information needed to continue the political process and to build support for the improved management and protection of the Dome.

Delineating the Central American Dome

The Central American Dome (also known as the Costa Rica Dome)[1] is a highly productive area of open ocean, situated in the northeastern tropical Pacific. The Dome was first observed in 1948 (Wyrtki, 1964) and first described by Cromwell (1958). It has been observed and studied several times since the late 1950s, following the development of a productive tuna fishery within the region (Fiedler, 2002). The Dome has since become a focus of scientific research to examine its significance as an important habitat for dolphins and other cetaceans, in particular endangered blue whales, and marine turtles (Fiedler, 2002, Palacios et al 2006, Shillinger et al, 2012). Recently it has also received attention for its uniquely high productivity and role in carbon cycling (Fiedler, 2002; Westberry et al, 2008). The Central American Dome can be defined as a shoaling of the generally strong, shallow thermocline with cold nutrient-rich upwelling (Fiedler, 2002). The upwelling of deep water at the Central American Dome results in an area of high primary production detectable by remote sensing, which can be considered a distinct biological habitat.

The Central American Dome varies in size and position throughout the year but the mean position is near 9°N 90°W, at the end of a thermocline ridge which shoals from west to east across the Pacific, between the westward North Equatorial Current and the Eastward North Equatorial Countercurrent. This ridge and the dome extend below the thermocline, to a depth of more than 300m. The Central American Dome is mainly located in the high seas, but also straddles the national waters of Costa Rica, Nicaragua, El Salvador, Guatemala and México. It is a distinct and highly productive biological habitat where phytoplankton and zooplankton biomass is higher than in surrounding tropical waters (Fiedler 2002). The dome forms near the coast in February-March forced by a coastal wind jet, before strengthening offshore between July and November and eventually diminishing by December-January (Saito et al, 2005; Hofmann et al. 1981).

Figure 1A below shows the extent of the limits of the Dome mapped according to average sea surface height, using an -0.5m contour line. The area fits within a quadrant defined by the coordinates 11° 24' N - 6° 22' N and 85° 52' W - 100°30' W. The center of the Dome has an average sea surface height of –1.5 m, and the map represents the current best estimate of the extent of the oceanographic feature.

The Central American Dome Ecologically or Biologically Significant Area (EBSA), as adopted by the Convention on Biological Diversity Regional Workshop for the Eastern Tropical and Temperate Pacific in August 2012, included further coastal area in the EBSA. Due to the dynamic nature of the Central American Dome, which forms near the coast in February-April, and subsequently migrates further offshore, the EBSA was considered to include the core area of the Dome and the area of its biological impact (as demonstrated by important blue whale and leatherback turtle habitat). The EBSA incorporates offshore oceanic waters and extends to encompass the Papagayo coastal upwelling region, as shown in figure IB.

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[1] While the oceanographic feature is known widely as the Costa Rica Dome in scientific and other literature, the Ecologically or Biologically Significant Area (EBSA) adopted by the East Pacific Regional Workshop of the Convention on Biological Diversity was named the "Central American Dome" in recognition of the fact that multiple countries share responsibilities for monitoring and managing the Dome region.

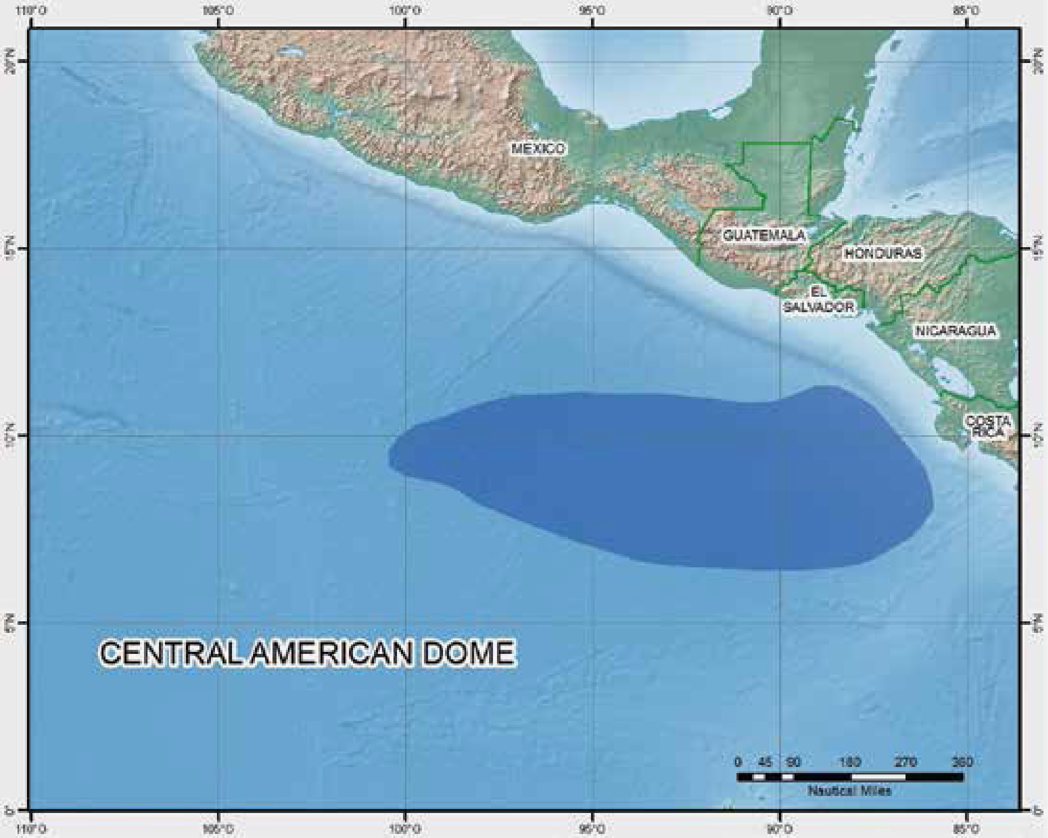

Figure IA: The extent of the limits of the Central American Dome mapped according to average sea surface height, using an -0.5m contour line. The area fits within a quadrant defined by the coordinates 11° 24' N - 6° 22' N and 85° 52' W - 100°30' W.

This represents the best current estimate of the extent of the Dome as an oceanographic feature.

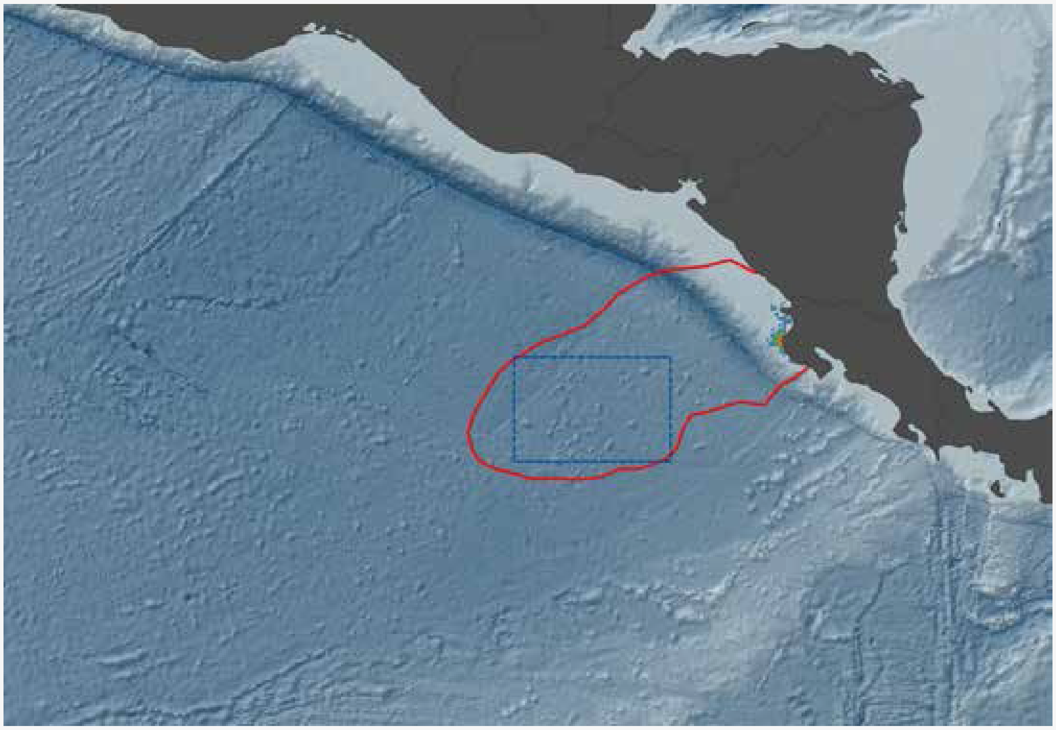

Figure 1B: The extent of the proposed CBD Central American Dome Ecologically or Biologically Significant Area (EBSA), taking into account the core of the dome (thermocline shoaling) and its biological impacts (extrapolated from key blue whale and leatherback turtle habitat).

Science and evidence for protection and management

The scientific case for protection for the Central American Dome consists of three interdependent components: (i) the highly productive ecosystem created through an interaction between wind and currents; (ii) the importance of this ecosystem to a variety of species, including endangered species such as the blue whale and the leatherback turtle; and (iii) the goods and services provided by the Dome both regionally and globally. In addition, there are threats to the Dome and the species using it as habitat. Together, these factors combine to make five compelling reasons for recognition, protection and better management of the Central American Dome. These reasons are summarised in Table 1 and each is discussed in more detail in the following sections.

The Central American Dome is a productive environment…

1. … of great ecological value
2. …of global importance as critical habitat for the endangered blue whale
3. …of global importance as habitat for the critically endangered leatherback turtle
4. …an area that provides tangible goods and benefits regionally and globally
5. …threatened and in need of management

Table 1: Five key reasons supporting the case for protection and improved management of the Central American Dome

1. The Central American Dome is a productive environment of great ecological value, with nutrient-rich waters supporting abundant plankton growth, which in turn support economically important fish and other animals at higher trophic levels. The Dome has very high concentrations of chlorophyll and is visible from space.

Physical oceanography at the Central American Dome

The Central American Dome is created through an interaction between wind and currents. It is an area of approximately 1,570,47 km2 (Fig. 1A). It is an area where cold water, upwelling from the deep ocean, rises to just below the warm tropical surface layer. Winds blowing through the gaps in the Central American cordillera, as well as ocean currents, push the warm water aside to allow for the rising of nutrient-rich cold water. The boundary between the warm surface water and cold deep water (called a thermocline) forms a dome-like feature, and gave the area its name (Hofmann et al, 1981; Xie et al, 2005; Ballestero, 2006; Kahru et al, 2007). The defining feature is the shallowness of the thermocline, which at the Central American Dome, often reaches to within 10 to 15m from the surface, compared to 30–40m to the north and south (Wyrtki, 1964; Fiedler, 2002). The Central American Dome is the peak of a thermocline ridge that shoals gradually from west to east before dropping off sharply between the dome and the coast (Hofman et al, 1981; Fiedler, 2002, Xie et al, 2005, Ballestero, 2006).

Because the Central American Dome is formed by wind and currents, its position changes from year to year and is constantly moving. It is associated with a cyclonic circulation of surface currents and is seasonally affected by large- and coastal-scale wind patterns (Kessler, 2006). Surface winds and currents in the region of the Central American Dome change seasonally as the inter-tropical convergence zone (ITCZ) moves north and south with the sun.
The Dome forms near the coast in

February-March due to wind forcing caused by the Papagayo wind jet. In May, the Papagayo winds weaken and the dome separates from the coast (Fiedler, 2002), before strengthening offshore in July due to the development of upwelling. The upwelling at the Dome persists throughout the summer and early fall. In November, the upwelled region is released, due to decreasing winds, as a wave propagating to the west along the thermocline ridge. The Dome diminishes by December-January (Hofmann et al, 1981; Saito et al, 2005). Figure 2, below, depicts the annual cycle of the Central American Dome.

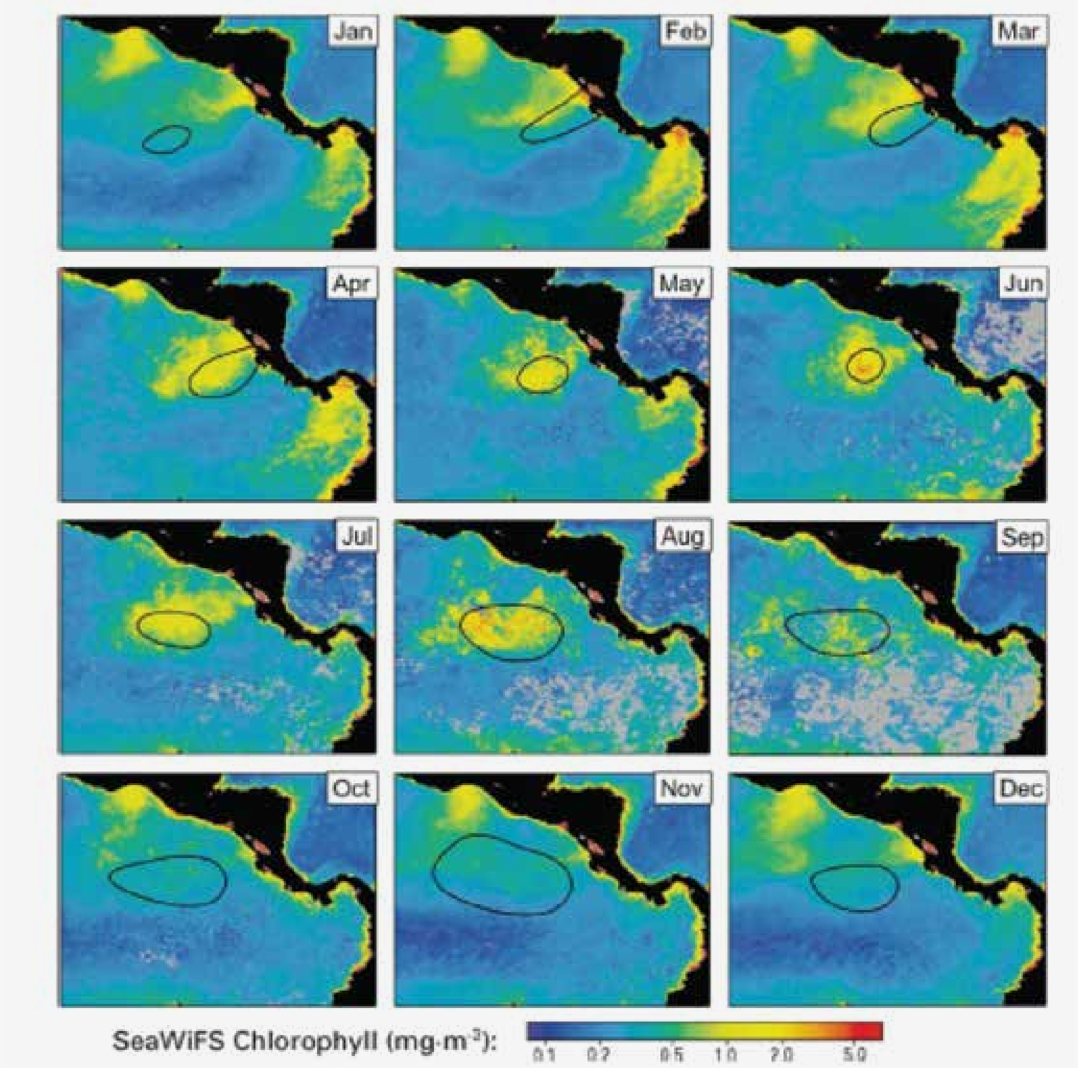

Figure 2: Monthly mean fields of SeaWifs chlorophyll concentration in the region of the Central American Dome. Note the annual cycle in location and magnitude of the Dome, forming at the coast in February and March and subsequently moving towards the open ocean. Figure from Fiedler, 2002.

There is a strong physical and biological interconnectivity between the coastal wind forcing in the Papagayo and Tehuantepec Coastal Regions and the Central American Dome. Wintertime winds through coastal mountain gaps contribute to the development of large-scale anticyclonic eddies within the Gulfs of Tehuantepec and Papagayo. These winds and the resulting eddies coincide with the peak nesting (December to February) and hatchling dispersal periods (January to April) of the endangered leatherback turtle. The costal eddies provide a mechanism through which leatherback hatchlings can be readily transported from the coast to offshore habitats within the Central American Dome region (Shillinger et al, 2012). Figures 3 and 4 (below) demonstrate the connectivity between the Papagayo and Tehuantepec coastal regions and the Central American Dome.

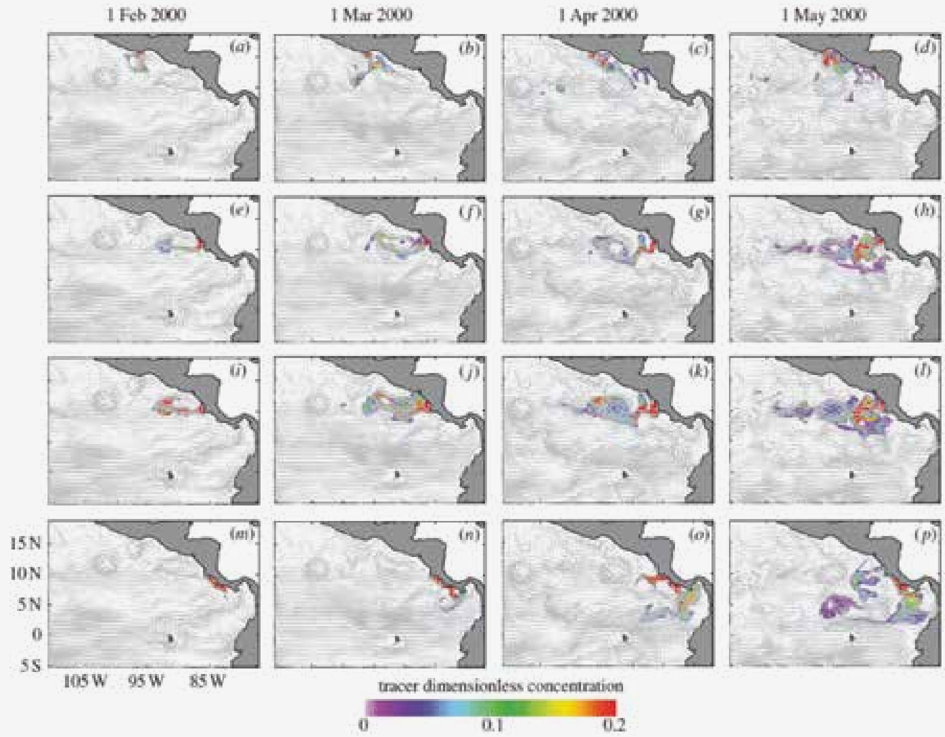

Figure 3: Monthly snapshots of modelled surface circulation (arrows) and tracer concentration (contours) for the year 2000 based on continuous tracer releases between 15 January and 15 April from nesting beaches at (a–d) Barra de la Cruz, (e–h) Playa Chacocente, (i–l) Playa Grande and (m–p) Playa Carate. Black dots show tracer release locations. The figure demonstrates the coastal eddy system that transports leatherback turtle hatchlings from nesting beaches to the Central American Dome region. Figure from Shillinger et al, 2012.

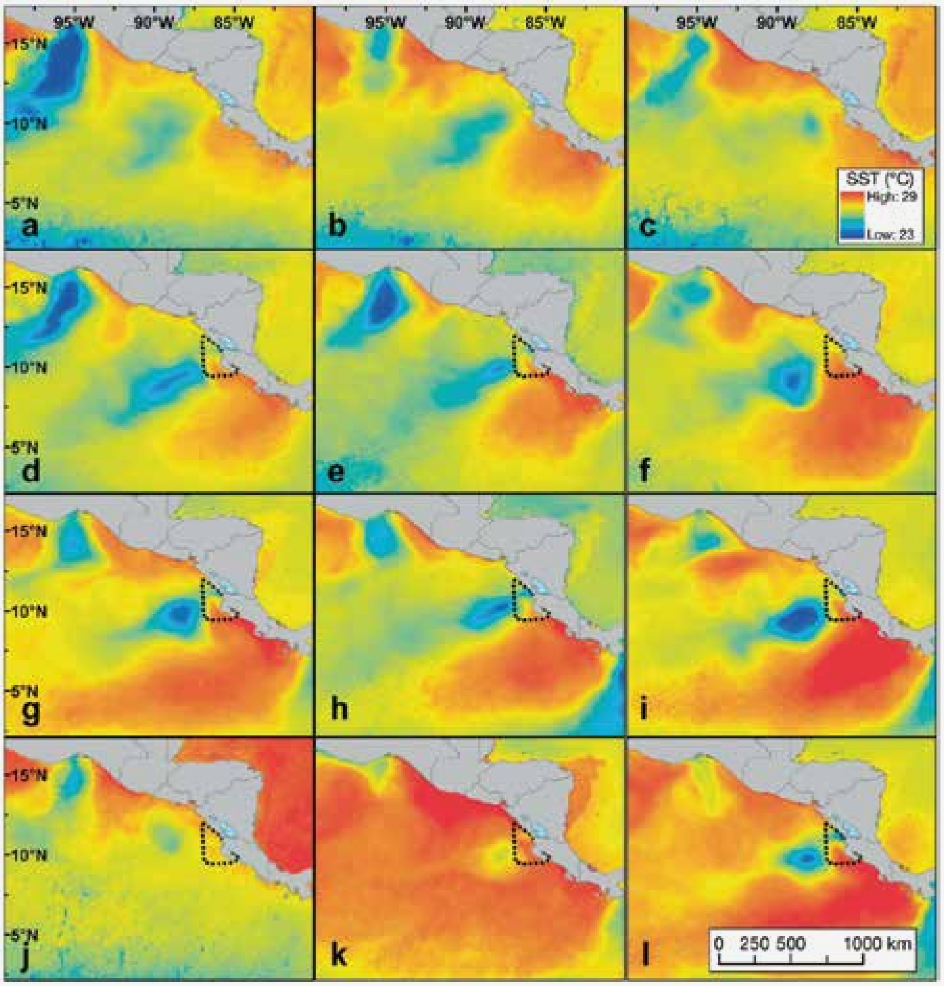

Figure 4: Monthly composite of mean sea surface temperatures (SST, °C) within the eastern Pacific region surrounding and encompassing the internesting region for leatherback turtles delineated by the minimum convex polygon (MCP) in Fig. 1, during (a) December 2004, (b) December 2005, (c) December 2007, (d) January 2004, (e) January 2005, (f) January 2007, (g) February 2004, (h) February 2005, (i) February 2007, (j) March 2004, (k) March 2005 and (l) March 2007. Dotted black line represents the MCP for turtle internesting habitat during 3 combined seasons. Images from NOAA GOES Imager, day and night, 0.05°, western hemisphere. The images demonstrate the physical and ecological connectivity between the coastal and offshore habitats in the Mesoamerican region. Figure from Shillinger et al, 2010.

The Central American Dome is similar to other tropical thermocline domes in several respects: it is part of an east–west thermocline ridge associated with equatorial circulation, surface currents flow cyclonically around it, and its seasonal evolution is affected by large-scale wind patterns. The Central American Dome is unique, because it is also forced by a coastal wind jet (Fiedler, 2002).

Due to upwelling, surface waters at the Central American Dome are lower in temperature and higher in nitrate and chlorophyll than surrounding areas, resulting in high levels of primary production (Broenkow, 1965; Chavez & Barber, 1987; Fiedler, 2002, Vilchis et al, 2006). Such upwelling areas can thus create unique, highly productive regions, making the oceanic habitat of the eastern tropical Pacific more heterogeneous and productive than other tropical oceans (Kessler 2002, Fiedler 2003, Ballesteros & Coen 2004; Vilchis et al, 2006). Dense populations of phytoplankton thrive in persistent upwelling regimes, and enhanced chlorophyll levels at the Central American Dome (associated with relatively higher biomass of phytoplankton and high nutrient levels) are visible in satellite imagery (see figure 2). The coupling between the shallow thermocline, the associated anomaly in sea level, and high concentrations of chlorophyll-a is tighter in the Central American Dome than has been previously recorded anywhere in the world ocean (Kahru et al, 2007). Zooplankton biomass is increased here and, perhaps consequently, abundance of at least two cetacean species is markedly higher in the vicinity than in the surrounding tropical waters (Au and Perryman, 1985; Reilly and Thayer, 1990; Fiedler, 2002; Ballance et al, 2006).

Upwelling associated with the cyclonic circulation, combined with the presence of a seasonally predictable strong and shallow thermocline, make the Central American Dome a distinct biological habitat, where phytoplankton and zooplankton biomass are higher than in surrounding tropical waters. The physical structure and biological productivity of the dome affect the distribution and feeding of whales and dolphins, probably through forage availability (Fiedler, 2002).

Biological communities at the Central American Dome

The highly productive Central American Dome provides habitat for abundant communities of phytoplankton and zooplankton, which in turn provide a source of food for squid, commercially important tunas and cetaceans, including the endangered blue whale. The Dome region is also transected by a migration corridor for critically endangered leatherback turtles. This section will discuss the current state of knowledge about biodiversity at the Dome, with in-depth sections describing the importance of the Dome to blue whales and leatherback turtles.

The phytoplankton community at the Central American Dome has been studied by, at least, Li et al (1983), Franck et al (2003) and Saito et al (2005). Each of these studies found that the phytoplankton community was dominated by cyanobacteria (Synechococcus sp.), with cell numbers more than an order of magnitude higher than in other oceanic environments. Saito et al (2005) also hypothesized that there may be a unique water column chemical signature that allows Synechococcus instead of larger eukaryotic phytoplankton to bloom. Their studies found higher than usual concentrations of natural cobalt ligands, and the flux of high cobalt into surface waters. The chemical attributes of the cobalt measured were highly unusual, and its source is not understood (Saito et al, 2005). Few studies have addressed the microbial community at the Dome, but some preliminary work indicates that

Alteromonas and Pseudoalteromonas are the most highly represented groups among bacteria (Krey, 2008).

The abundant phytoplankton growth supports higher-than-usual abundances of zooplankton at the Central American Dome (Fiedler, 2002). An important component of the zooplankton community consists of dense patches of euphausiids (krill) at various depths, which blue whales are thought to dive to feed on. These patches have been found to be of importance to the distribution of blue whales, with the total acoustic scattering from patches being a key feature in predicting blue whale proximity (Matteson, 2009).

A high abundance of jumbo flying squid (Dosidicus gigas) has been reported around the Dome, which is thought to be a hatchery area for the species (Waluda and Rodhouse, 2006), and which supports an important commercial fishery. It is likely that the higher chlorophyll-a concentrations found in the Central American Dome may lead to a favourable feeding ground for the jumbo flying squid and the oceanographic conditions in the area may retain them there. Similarly, large yellowfin tuna (Thunnus albacares) are common around the Central American Dome and likely also feed there (Ichii et al, 2002). Consequently, the Dome area supports a commercial tuna fishery (Yamagata, 1992, Fiedler, 2002, FAO, 2005). While seabird data is scarce from the area, thermocline topography is a key variable in predicting distribution and abundance of seabirds in this area, probably due to its influence on the availability of seabird prey (Vilchis et al, 2006; Ballance et al., 2006).

The Central American Dome is significant for cetaceans, particularly blue whales and short-beaked common dolphins. Both of these species are found in great abundance at the Dome, likely due to the availability of food (euphausiids for blue whales and mesopelagic fishes and squids for the dolphins) (Ballance et al, 2006). The body of research related to the Central American Dome as habitat for blue whales is extensive, and is summarized in the next section. Less information is available on dolphin species beyond the short-beaked common dolphin (Delphinus delphis) and pantropical spotted dolphin (Stenella attenuata), although cruise reports from the area contain sightings of a number of dolphin species as well as other cetaceans, such as humpback whales (Megaptera novaeangliae) (Hoyt, 2009A). Additionally, a study based on extensive delphinid sighting data and modelling of dynamic environmental and fixed geographic variables predicted that the Central American Dome would be one of the areas with highest delphinid densities in the eastern tropical Pacific Ocean (Ferguson et al, 2005). Figure 5 (below) shows a map of dolphin sightings from the eastern tropical Pacific, with concentrations apparent in the Dome area. Further field research would be required to develop a more precise list of cetacean and other biodiversity in the area.

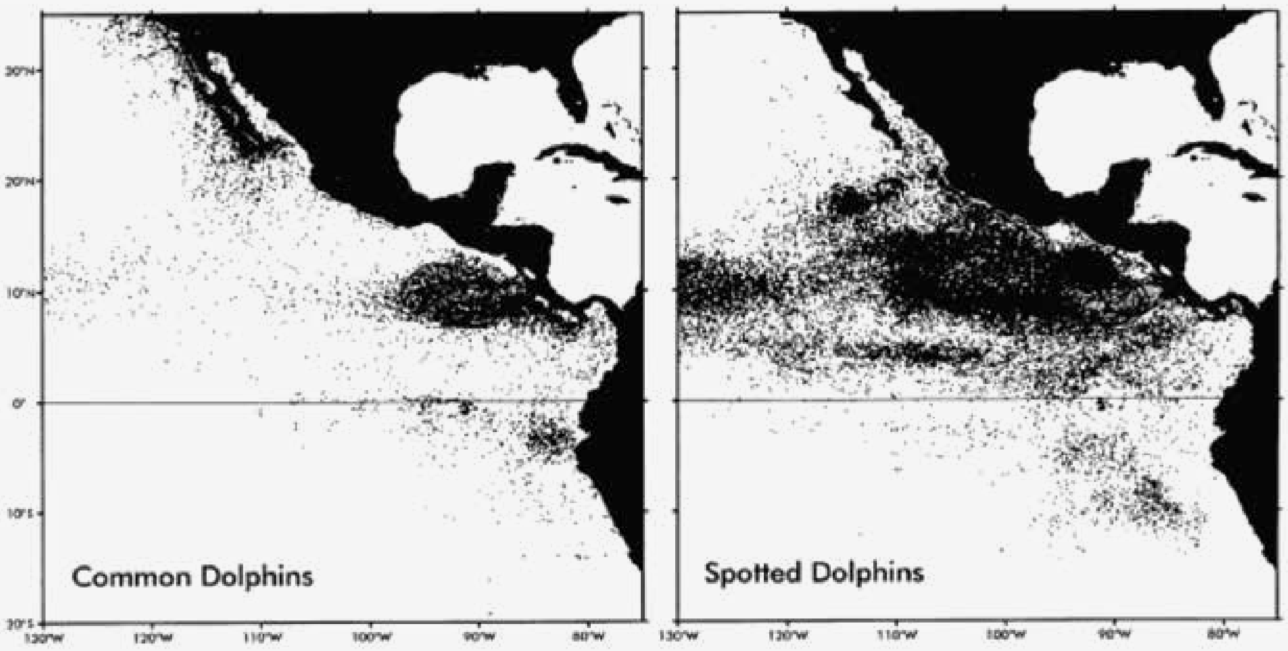

Figure 5: Sighting locations of common dolphins (Delphinus delphis) and spotted dolphins (Stenella attenuata) from research and tuna vessels in the NOAA/NMFS/SWFSC sightings database (1971–1999). Figure from Fiedler, 2002.

2. The Central American Dome is of global importance as critical habitat for the endangered blue whale, providing a unique area for feeding, breeding, calving and raising calves. The Dome is occupied by blue whales year-round.

The Central American Dome is notable for being a unique year-round habitat for the blue whale *(Balaenoptera musculus)*. The blue whale is the largest animal ever to have lived, and is classified as an endangered species on the IUCN Red List, but may in fact meet the criterion for critically endangered (Reilly et al, 2008). There are nine distinct blue whale populations in the world (classified by song, McDonald et al, 2006). The Eastern North Pacific blue whale population, estimated at approximately 3000 individuals, represents the largest remaining blue whale population on earth (Calambokidis and Barlow 2004). For a portion of this blue whale population, the Dome provides an area for feeding, mating, breeding, calving and raising calves (Mate et al, 1999; Hoyt, 2009A; Hoyt, 2011; Hoyt and Tetley 2011). It may be an important habitat for the survival and recovery of this population (Matteson, 2009), and forms a key component in a network of blue whale habitat sites, several of which have already been partially protected off the California coast and in the Gulf of California, off México. However, most blue whale habitat in the eastern North Pacific has no formal protection.

Early evidence of the importance of the Central American Dome as blue whale habitat came from whale sightings by scientists onboard research vessels (e.g. Wade & Friedrichsen, 1979; Reilly & Thayer, 1990). Reilly and Thayer (1990) analyzed the distribution of blue whales from sightings made during research cruises in the eastern tropical Pacific, discovering that over 90% of the sightings were made in just two locations: along Baja California and in the vicinity of the Central American Dome. Later satellite tracking studies have linked the Baja California population of blue whales to those sighted at the Central American

Dome, indicating that the Central American Dome may be a calving/breeding area for North Pacific blue whales (Mate et al., 1999, Branch et al, 2007). Satellite tracking and modelling studies by Bailey et al (2009) resulted in maps that tracked the migration and foraging behaviours of blue whales between Baja California and an area west of the Central American Dome, proposing that the Central American Dome may represent an important migration corridor for the whales, and noting possible foraging behaviour linked to enhanced euphausiid standing stocks in the area (Bailey et al, 2009; Reilly and Thayer, 1990; Fiedler, 2002; Ballance et al, 2006). Figure 6 provides a map showing blue whale migratory routes from Baja California to the Central American Dome resulting from the Bailey et al (2009) study.

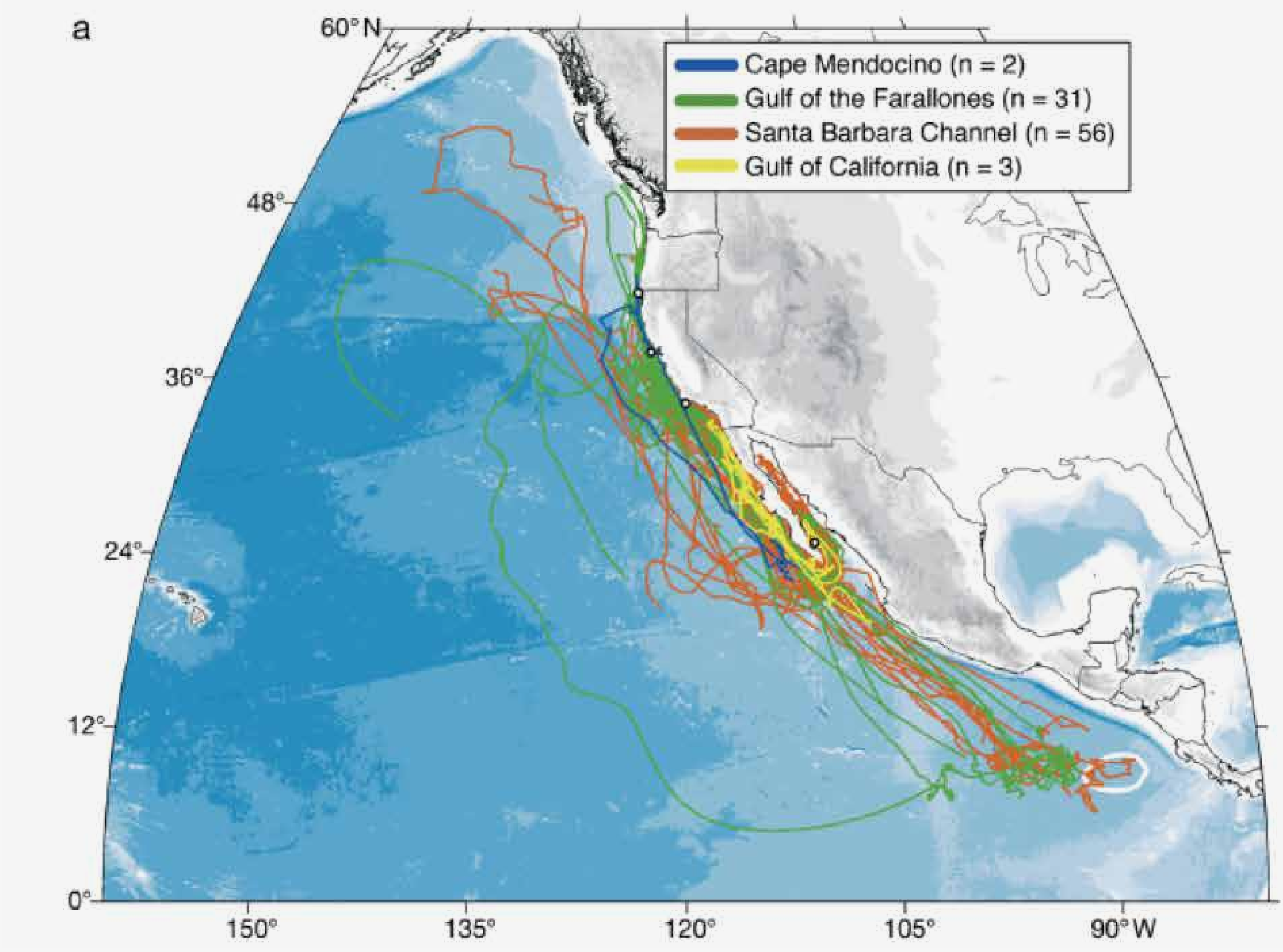

Figure 6: Individual tracks for 92 tags on blue whales deployed between 1994 and 2007. The Central American Dome is shown as white contour. From Bailey et al, 2009.

Research results have also shown that the Dome region is occupied by blue whales year round (Reilly & Thayer, 1990; Calambokidis and Barlow, 2004), suggesting either the presence of a resident population or that both northern and southern hemisphere whales visit, with temporal overlap. If a resident population is present, it is not known whether it might be a distinct, non-migratory population segment or whether some individuals may choose not to migrate every year (Calambokidis and Barlow, 2004). It has also been suggested, but not confirmed, that at least some blue whales may originate from the southern hemisphere (e.g. off Chile), migrating across the Equator to the Central American Dome (IWC, 2008). The source of the year-round population is still unknown and subject to further research.

Studies of blue whale migrations between Baja California and the Central American Dome and its vicinity have provided new insight into blue whale behaviours. The commonly-held view of blue whale (and other large baleen whale) life strategy has been that it consist of seasonal migrations between productive, high latitude feeding grounds in the summer and unproductive, low-latitude breeding grounds in the winter, where feeding does not take place (Mackintosh 1965; Bailey, 2009). However, blue whales have been seen routinely feeding at the Central American Dome (Hoyt, 2009A; Mate et al, 1999, Reilly and Thayer, 1990). Because of the high productivity and standing stocks of the Central American Dome, Reilly and Thayer (1990) hypothesized that blue whales may select low latitude sites that permit foraging. This hypothesis has been strengthened by the study of other similar blue whale populations around the world, leading to a suggestion that some populations of blue whales may use an alternative life strategy by selecting and exploiting predictable productive areas located in low- and mid-latitudes, which are most conducive to feeding success (Rasmussen et al, 2007). The high productivity of the Central American Dome may allow blue whales to feed during their winter calving/breeding season, unlike gray whales (Eschrichtius robustus) and humpbacks (Megaptera novaeangliae) which fast during that period (Mate et al, 1999). A study of blue whale migratory and foraging behaviours between Baja California and the Central American Dome (Bailey et al, 2009) also indicated the whales may forage year-round. Matteson (2009) confirmed that feeding takes place at the Central American Dome through collection of fecal samples from whales in the area. She also suggested that while foraging during the winter reproductive season is not typical of baleen whales, year-around foraging may be an important element in the survival and recovery of blue whale populations.

3. The Central American Dome is of global importance as habitat for the critically endangered leatherback turtle, providing a migratory path and potential feeding area for adult turtles, as well as critical habitat for young hatchling turtles leaving their Central American nesting beaches.

Leatherback turtles (Dermochelys coriacea), classified as critically endangered on the 2010 IUCN Red List of Threatened Species, are the widest-ranging marine turtle species, and are known to migrate across entire ocean basins. (Bailey et al, 2012). The Central American Dome and the surrounding area encompass an important migratory path for a population of endangered leatherback turtles nesting in Costa Rica (Shillinger et al., 2008, Shillinger et al., 2010, Shillinger et al., 2011) and may also provide critical habitat for neonate turtles (Shillinger et al., 2012). Populations of leatherback turtles in the eastern Pacific have declined by >90% during the past two decades, primarily due to unsustainable egg harvest and fisheries bycatch mortality (Spotila et al. 2000). While research and conservation efforts on nesting beaches are ongoing, relatively little is known about the eastern Pacific leatherback populations' oceanic habitat use and migration pathways. Continued and rapid declines of this critically endangered population underscore the urgent need to develop conservation strategies across all life stages.

Shillinger et al, (2008) analyzed the largest multi-year satellite tracking data set for leatherback turtles from their largest nesting colony at Playa Grande, Costa Rica. Their study describes the migrations, habitats, and dispersal of female leatherbacks, and the predictable effects of ocean currents on their migration. After completing nesting, the turtles headed southward, traversing the dynamic equatorial currents with rapid, directed movements. In contrast to the highly varied dispersal patterns seen in many other sea turtle populations, leatherbacks from Playa Grande traveled within a persistent migration corridor from Costa Rica, past the equator, and into the South Pacific Gyre, a vast, low-energy, low-productivity region. The migratory path of the turtles is shown in figure 7 (below). The turtles' migration took them between the southern edge of the Central American Dome and the Costa Rica Coastal Current. They then crossed the energetic flow along the southern edge of the Central American Dome between 8 °N and 6 °N on a SE heading. Once outside the Central American Dome, they turned WSW before continuing westward aided by the South Equatorial Current. This study indicates that the Central American Dome is part of the migratory corridor of the leatherback turtle, and that the oceanographic features in this area play a role in this migration.

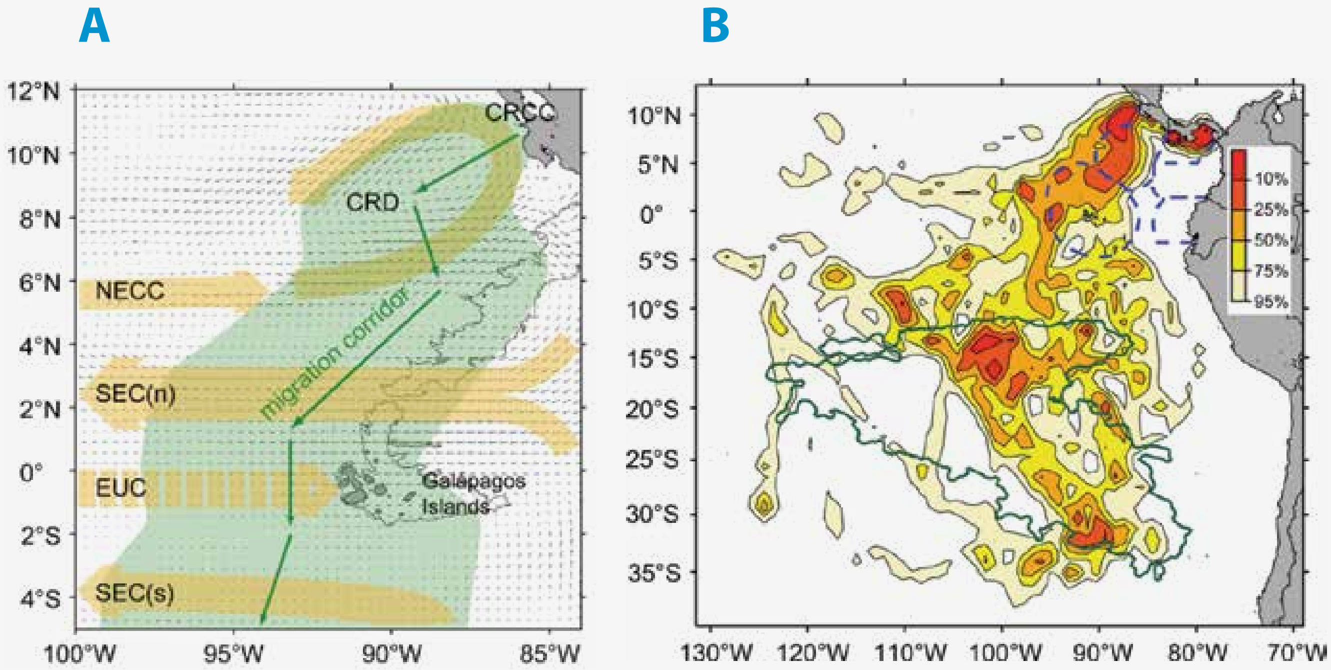

Figure 7: Leatherback turtle migrations. Figure A shows a schematic of turtle migration corridor through the equatorial current system, based on the 75% home-range utilization distribution contour. Figure B shows a combined utilization distribution by eastern Pacific leatherback turtles from all tracking data (for years 2004, 2005 and 2007). Note the presence of the Central American Dome in the high utilization area. From Shillinger et al, 2008.

Shillinger at al. (2012) hypothesize that the Central American Dome region may also provide critical habitat for neonate leatherback turtles, whose post-hatchling departure routes link coastal Mesoamerican nesting beaches to pelagic nursery habitats. Their study investigated leatherback hatchling dispersal from four Mesoamerican nesting beaches (Barra de la Cruz, Mexico: 15.88 N, 95.98 W; Playa Chacocente, Nicaragua: 11.58 N, 86.28 W; Playa Grande, Costa Rica: 10.38 N, 85.98 W; and Playa Carate, Costa Rica: 8.48 N, 83.48 W) using passive tracer experiments within a regional ocean modelling system (ROMS). The region offshore of the Pacific coast of Mesoamerica is characterized by dynamic ocean conditions. Wintertime winds through coastal mountain gaps contribute to the development of large-scale anti-cyclonic eddies within the Gulfs of Tehuantepec and Papagayo; intense and stable features that can last for up to six months and propagate more than 2000 km offshore from the continental margin, transporting nutrient-rich coastal waters and organisms into the ocean interior. The evolution of tracer distribution from each of the nesting beaches showed the strong influence of eddy transport and coastal currents. Modeled hatchlings from Playa Grande, Costa Rica, were most likely to be entrained and transported offshore by large-scale eddies coincident with the peak leatherback nesting and hatchling emergence period (see figure 8). Shillinger et al. posit that these eddies potentially serve as ‘hatchling highways’, providing a means of rapid offshore transport away from predation and a productive refuge within which newly hatched turtles can develop. The results from their model support the hypothesis that hatchling leatherbacks emerging from nests in late winter at Playa Grande and other Mesoamerican nesting beaches can be rapidly and efficiently transported offshore within Papagayo eddies. Because turtles face increased predation risk near the beach, quick offshore transport is likely to increase the probability of survival. Moreover, these eddies provide a productive refuge within which newly hatched turtles can develop.

Long-term (2000-2008) mean tracer concentration at 1 June based on continuous tracer releases between 15 January and 15 April from nesting beaches at (a) Barra de la Cruz, (b) Playa Chacocente, (c) Playa Grande and (d) Playa Carate.

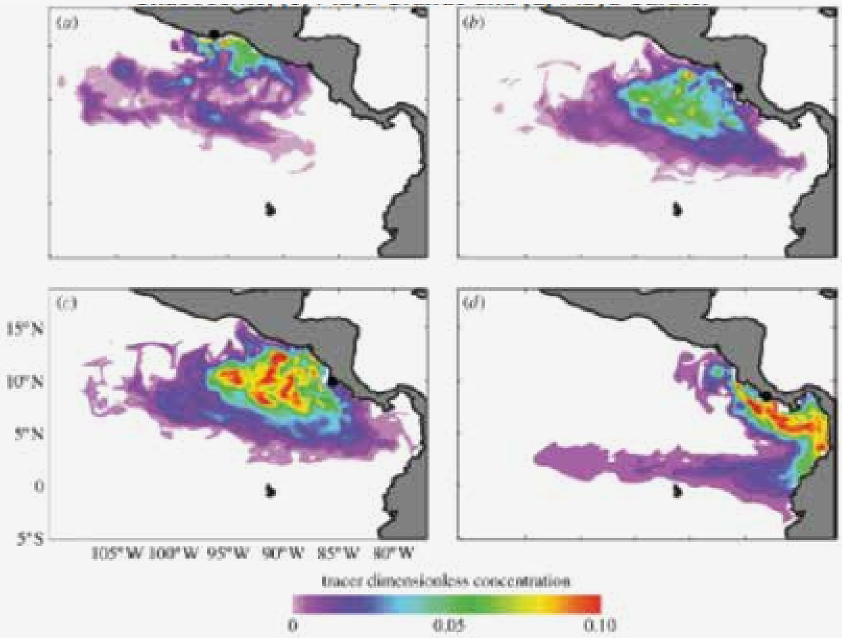

Figure 8. The likely transport of hatchlings from nesting beaches based on tracer releases. From Shillinger et al, 2012.

Shillinger G L et al. Proc. R. Soc. B
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A subsequent study by Bailey et al (2012) mapped tracking data for leatherback turtle populations throughout the Pacific Ocean. Turtles tagged at Playa Grande, Costa Rica, are shown to migrate through the Central American Dome and its surrounding area (see figure 9). The study also found that in the eastern Pacific, tagged turtles often exhibited behaviour related to searching for food in areas of upwelling, likely because such areas increase transport of nutrients and consequently prey availability (Shillinger et al. 2011, Bailey et al, 2012). Further research is required to fully understand turtles' response to oceanographic conditions.

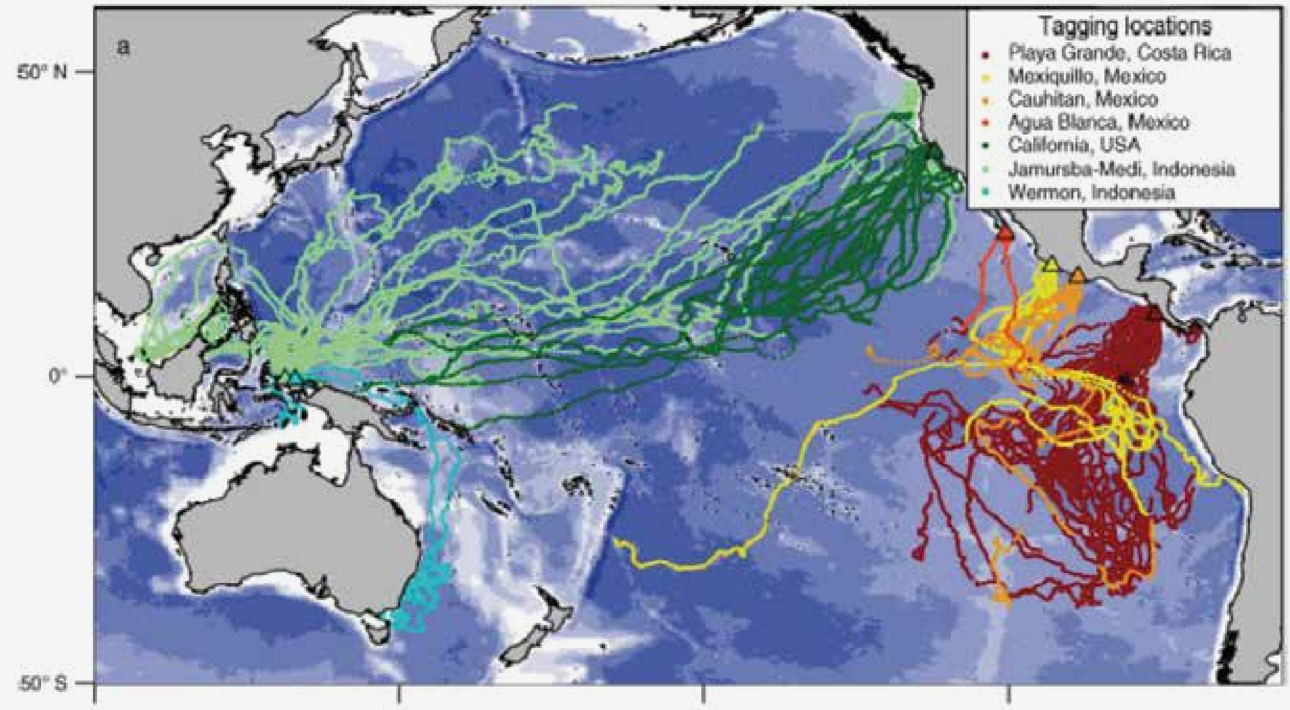

Figure 9: Switching state-space model (SSSM)-derived daily positions for 135 tracks on Pacific leatherback turtles, color coded by tagging location and overlaid on bathymetry. From Bailey et al, 2012. Tracks in brown belong to turtles tagged at Playa Grande, Costa Rica, and are shown to migrate through the Central American Dome and its surrounding area.

In order to ensure that management and conservation efforts within the Central American Dome region are meaningful for leatherbacks, improved and sustained conservation and management of Mesoamerican nesting beaches and interesting habitats (ranging to ~ 100 km from the coast) is essential. During the nesting season, adult female leatherback turtles nest multiple times and occupy coastal marine habitats near their nesting beaches. Shillinger et al. (2011) found that variability in the thermal environment drives considerable interannual variation in the shape and area of the larger utilization distribution (UD) polygons (Figure 10). This research suggested that interannual changes in oceanographic conditions, even at small or local scales (e.g. internesting region), can influence the behavior and distribution of internesting leatherback turtles. Taken together with the findings from Shillinger et al. (2008, 2010, and 2012), these results validate the importance of Parque Nacional Marino Las Baulas (PNMB) as a critical habitat for internesting leatherback turtles, but also suggest that expanded protection measures may be warranted and that these measures should consider the influences of regional environmental variation on the near-shore turtle movements and behaviors of internesting turtles, as well as opportunities for integration of conservation and management connectivity (i.e. migration corridor and putative hatchling dispersal habitats) with other life-history stages (hatchling and post-nesting dispersal).

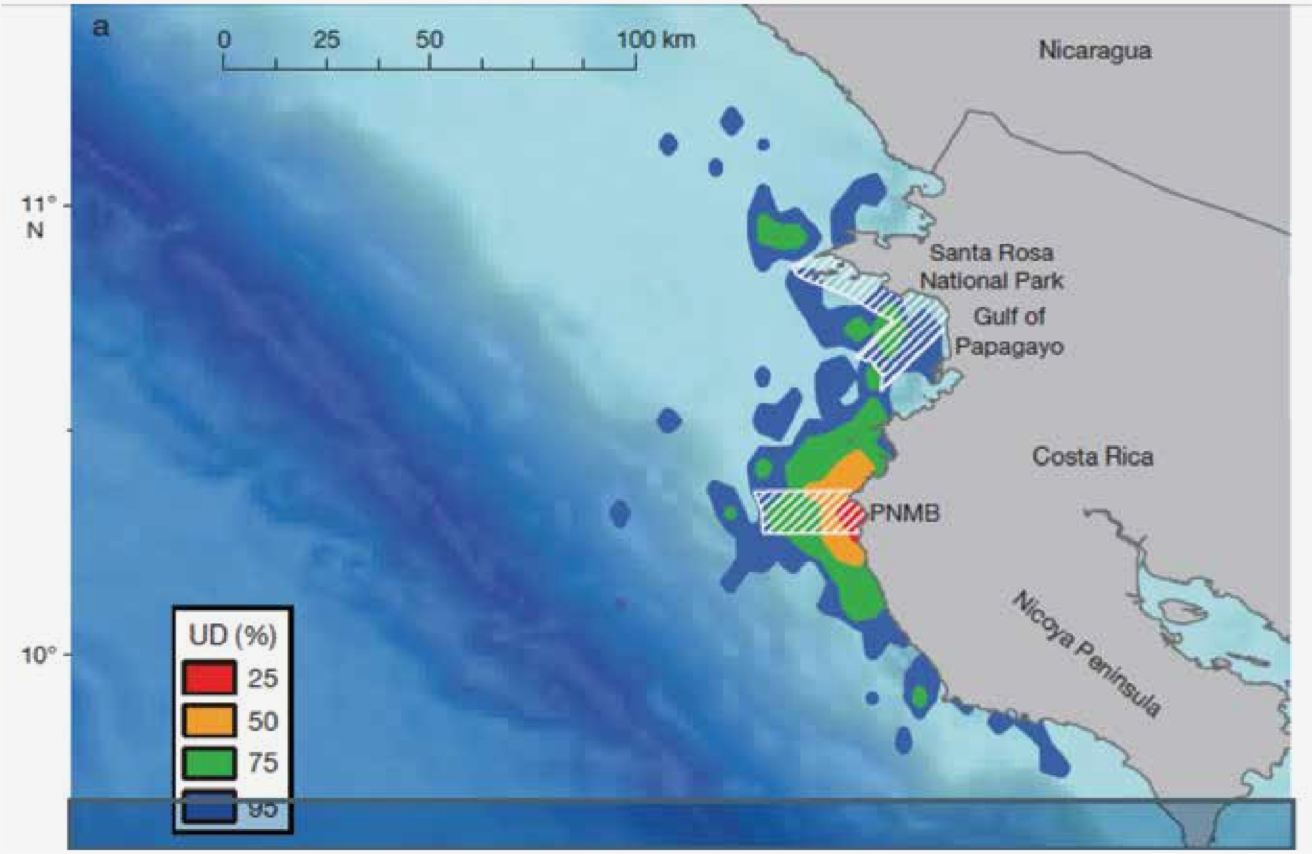

Figure 10: Dermochelys coriacea. Utilization distribution (UD) of internesting region occupied by 46 leatherback turtles during (a) all years combined. Polygons bordered and cross-hatched in white are Playa Grande National Marine Park (PNMB) and Santa Rosa National Marine Park (PNMSR).

4. The Central American Dome is an area that provides tangible goods and benefits regionally and globally. Containing some of the highest primary productivity in the world, the Central American Dome is a key site for carbon sequestration into the ocean. The high productivity within the Dome supports rich tuna and squid fisheries, as well as migratory species, which in turn provide tourism income for communities in the region. The Central American Dome has global value as an important area for research, which has been the source of scientific insights, and may yield new discoveries in the future.

The Central American Dome has an important role to play globally in carbon sequestration, climate change mitigation and maintenance of the Earth's climate

Highly productive areas, such as the Central American Dome, have an important role to play in the maintenance of the Earth's climate. Research undertaken during the last decades has confirmed the importance of ocean biology in controlling the carbon dioxide (CO_2) content of the atmosphere (Williamson and Holligan, 1990). Organic matter containing carbon is transported from ocean surface to deeper layers by the so-called biological pump. Marine plants, particularly phytoplankton in the open ocean, take up CO_2 during photosynthesis. Recent research has shown that photosynthesis by ocean phytoplankton amounts to approximately half of the photosynthesis on Earth, and is a vital link in the cycling of carbon between living and inorganic stocks. Each day, more than a hundred million tons of carbon in the form of CO_2 are fixed into organic material by phytoplankton, and each day a similar amount of organic carbon is transferred into marine ecosystems by sinking and grazing (Behrenfeld et al, 2006). The carbon is transported to the deep ocean as dead organisms and other organic detritus sinks down through the water column, where much of it is consumed by microbes, zooplankton and other filter feeding animals, thus providing an important energy source for animals living in the middle and deep layers of the ocean. The rest of the organic detritus ends up buried in seabed sediments for millions of years. The result is a net flow of carbon from the atmosphere and terrestrial environment into the world's oceans. Besides providing a climate regulating services, the biological pump also recycles nutrients and provides food for deep-dwelling species (Armstrong et al, 2010). It has been estimated that 50% of the carbon in the atmosphere becomes bound or 'sequestered' in natural systems is cycled into the seas and oceans. Oceans not only represent the largest long-term sink for carbon but they also store and redistribute CO_2. Some 93% of the earth's CO_2 is stored and cycled through the oceans (Armstrong et al, 2010).

The distribution of phytoplankton biomass and, by extension, of primary productivity is controlled by the availability of light and nutrients (nitrogen, phosphate, iron). These growth-limiting factors are in turn regulated by physical processes: ocean circulation, mixed-layer dynamics, upwelling, atmospheric dust deposition, and the solar cycle. (Behrenfeld et al, 2006; Williamson and Holligan, 1990). The Central American Dome has a high rate of annual primary production, fueled by readily-accessible nutrient-rich water due to upwelling (Broenkow, 1965). Satellite remote sensing, together with sophisticated algorithms and field measurements have improved global estimates of primary productivity. Calculations of net primary production by Westberry et al (2008) showed that maximum values in the oceans (approximately 1500 mg C^{m-2} d^{-1}) are confined to productive upwelling regions such as the Central American Dome, the Gulf of Tehuantepec, Peru, and the Benguela Current system. Sustained values near 500 mg C^{m-2} d^{-1} are found throughout much of the tropical ocean, except for the central oligotrophic gyres. The maps produced by Westberry et al (see figure 11) demonstrate the high net primary production at the Central American Dome in relation to much of the global ocean.

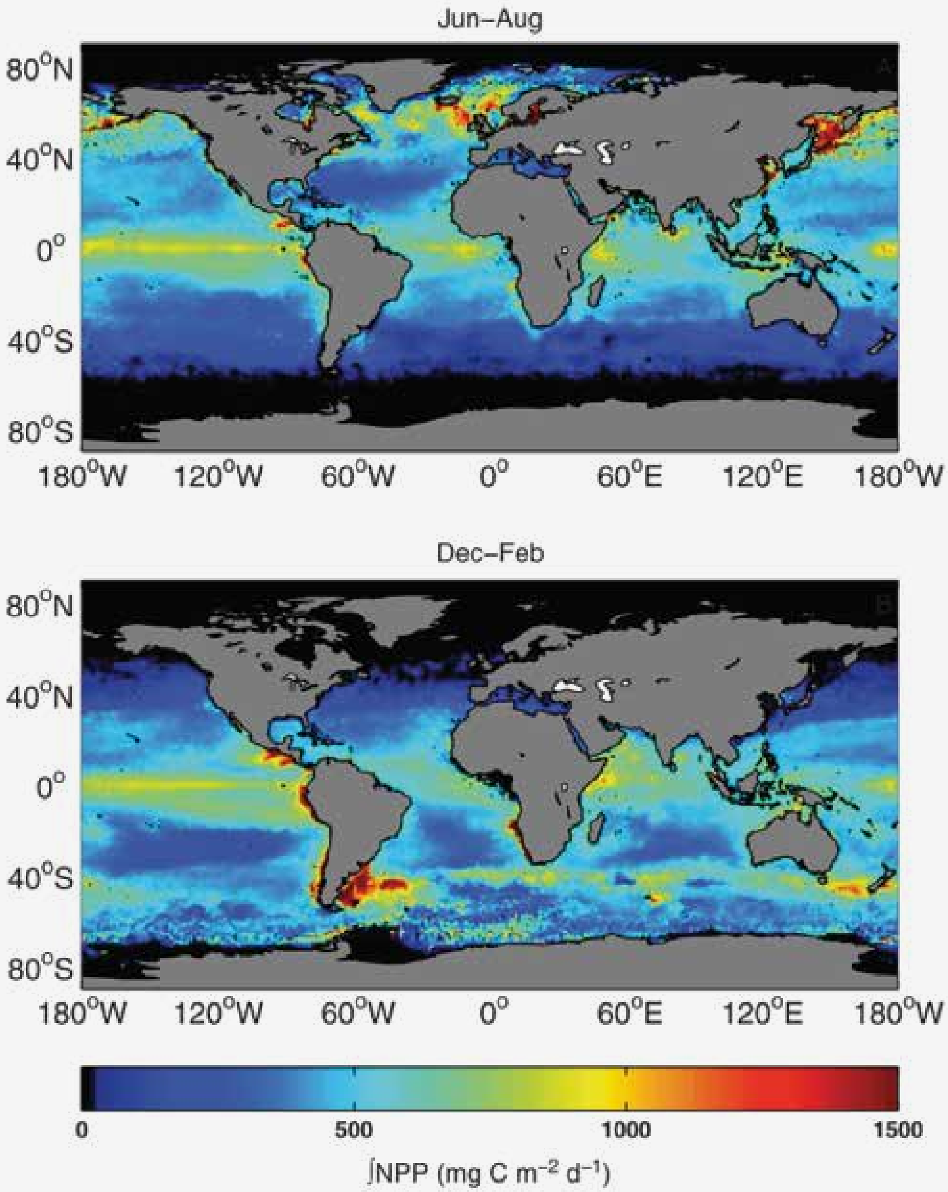

Figure 11: Depth-integrated net primary production (mg C m-2 d-1) for the boreal summer (top) and boreal winter (bottom). Values are climatological means calculated for 1999-2004. Figure from Westberry et al, 2008.

The high productivity is not only important for the maintenance of the Earth's climate, but also results in increased zooplankton biomass and a higher abundance of species, such as tuna and some cetacean species, as discussed in previous sections (Au and Perryman, 1985; Reilly and Thayer, 1990; Fiedler, 2002; Ballance et al, 2006).

The Central American Dome supports rich and economically important fisheries

The Central American Dome supports important pelagic fisheries, particularly for tunas and squids (FAO, 2005), and is important for national and global economies and for provision of food. A productive tuna fishery developed in the Central American Dome area in the 1950s (Fiedler, 2002) and this region is currently the site of a major yellowfin tuna fishery (Pennington et al, 2006). In fact, the Eastern Tropical Pacific Ocean in its entirety is the second largest tuna fishing area in the world, an important source of yellowfin and skipjack, and a birthplace of today's modern tuna industry (Trutanich, 2005).

While catch figures specific for the Central American Dome are not available, they are collected for the Eastern Pacific Ocean as a whole by the Inter-American Tropical Tuna Commission (IATTC), which is responsible for the conservation and management of tunas and other species taken by tuna-fishing vessels in the Eastern Pacific Ocean. The catches for yellowfin tuna in the Eastern Pacific Ocean have increased between the years 1982 and 2011. The largest catch on record took place in 2002 and was 443,000 tonnes. During 2004-2009 catches decreased substantially, and the 2011 recorded catch was 203,000 tonnes, which was greater than the catches during 2006-2008, but less than the catches during 1996-2005 (IATTC, 2012).

Catches are taken both by purse-seine sets on yellowfin associated with dolphins and unassociated schools, as well as by long line vessels. Distant-water longline fleets of China, Chinese Taipei, French Polynesia, Japan, the Republic of Korea, Spain, the United States and Vanuatu, fish for tuna in the Eastern Pacific. Bigeye and yellowfin tunas make up the majority of the catches by most of these vessels (IATTC, 2012). While there is uncertainty about recent and future levels of recruitment and biomass, it seems that caches presently are below the maximum sustainable yield (MSY) (IATTC, 2012).

The Central American Dome is also a hatching area for the jumbo flying squid (Dosidicus gigas) (Waluda and Rodhouse, 2006). This species supports the largest cephalopod fishery in the Eastern Pacific, with both commercial and artisanal fleets operating off the coasts of Peru, Mexico (Gulf of California), Central America and Chile (Waluda and Rodhouse, 2006, Ichii et al, 2002). The jumbo flying squid fishery is one of the largest fisheries in the Central Eastern Pacific as measured by annual tonnage caught, and is the largest cephalopod fishery in the world. Global landings of jumbo flying squid were 815,978 tonnes in 2010 (ftp://ftp.fao.org/fi/stat/summary/a1e.pdf). The commercial fishery consists of a multinational jigging fleet, which fish at night using powerful lights to attract squid. The species is caught to serve the European community market (mainly Spain, Italy, France and Ireland), Russia, China, Japan, Southeast Asian and increasingly North and South American markets.

The squid is also an important part of the food web in the area (Ichii et al, 2002). Squid abundance is likely supported by an increase in prey species such as small fishes, crustaceans and other animal plankton, which are in turn linked to the increased primary and secondary productivity at the Central American Dome (Waluda and Rodhouse, 2006). In turn, yellowfin tuna prey on subadult squid (Nigmatullin et al. 2001), and sperm whales are major predators of adult squids in the Eastern Pacific (Clarke & Paliza 2001) (Waluda and Rodhouse, 2006).

The Central American Dome and its adjacent waters are considered to be a potential spawning ground for the jumbo flying squid because of presence not only of a high proportion of mature squid but also mated females and larvae. Increased upwelling in the vicinity of the Dome, and a well-developed countercurrent thermocline ridge, is likely to be responsible for the accumulation of adult squid, including mated females and the retention of larvae in a region favourable for hatching and development (Vecchione 1999, Ichii et al. 2002, Chen et al, 2011) Favourable reproductive habitat tends to be associated with food enrichment, concentrated patch structure, and flow mechanisms that enable the population to maintain itself as a cohesive unit (Bakun & Csirke 1998), all of which are fulfilled by the Central American Dome system (Waluda and Rodhouse, 2006).

It has also been suggested that the Central American Dome is a spawning area that provides for the dispersal of squid to important squid fishery areas in Peru in the south and the Gulf of California to the north (Nigmatullin et al. 2001, Waluda et al. 2006). The jumbo flying squid exhibits latitudinally separated spawning and feeding areas (Waluda et al. 2004), taking advantage of seasonal productivity patterns, with hatching taking place in warmer areas close to the equator and feeding in cooler more productive high- to mid-latitude regions (O'Dor 1992, Waluda and Rodhouse, 2006). While the population structure of the jumbo flying squid is still unclear, this hypothesis is supported by a positive relationship between squid catches in the Gulf of California (Moralez-Bojorquez et al. 2001) and Peru, and hatching-favourable sea surface temperature at the Central American Dome in April prior to the start of the fishery (Waluda and Rodhouse, 2006). It therefore appears that increased upwelling and higher primary productivity in both the spawning area close to the Central American Dome and fishery area off Peru appears to have supported the largest fisheries in this region over the last decade.

The jumbo flying squid have a complicated intra-specific population structure and large spatial variability in the key life history parameters. (Chen et al, 2011). El Niño and La Niña events are likely to influence the size and position of the Central Dome (Fiedler, 2002), and thus the area available for spawning and development (Waluda and Rodhouse, 2006). The population size and distribution of the jumbo flying squid responds to ENSO variability and the species may be an indicator of climate change in the Eastern Pacific, and thus important for future research related to this topic (Waluda and Rodhouse, 2006, Olsen and Young, 2007).

The Central American Dome is a contributor to tourism revenue, helping provide support for communities from turtle and whale watching

Goods and services provided by marine turtles are valued by societies around the world. Within different cultures, marine turtles are variously recognized as deities, as possessing intrinsic ecological or aesthetic values, or are utilized for economic purposes including as food and medicine. (Vargas-Mena, 2000). In many places around the world, marine turtles are providing a new and expanding source of income through tourism revenue to coastal communities.

The leatherback population nesting at Playa Grande, and migrating through the Central American Dome, has become a major tourist attraction. Playa Grande is one of the main leatherback rookeries in the Eastern Pacific (Spotila et al. 1996), and it has been a tourism site since the early 1990's. Playa Grande and nearby nesting beaches form part of the Las Baulas Marine National Park (PNMLB). Gutic (1994) estimated that a third or US$1,350,960 of the gross tourism revenue for the area adjacent to the national park was generated by the leatherback turtles and the natural resources of the estuary at the southern end of Playa Grande. The leatherback population alone generated two thirds of that revenue, corresponding to US$900,460 in 1993 (Gutic, 1993, 1994), a number which would be markedly higher in today's values. During the 2001/2002 leatherback nesting season, 4,234 tourists (82% international visitors) spent an estimated US$81,276 on fees and tours to observe leatherback nesting. Average spending for all services associated with the visit to see the leatherback turtles is estimated at

US$338-US$676 per visitor. Gross annual revenue to tourism operators, business owners and their employees in Las Baulas de Guanacaste National Park is estimated at US$2,113,176 (Troëng and Drews, 2004).

Tourism based on marine turtles, including leatherbacks, also exists on the Pacific coast of Nicaragua, but on a much smaller scale. There are no economic estimates currently available for the value of these tourism operations.

Whale watching is another popular tourism activity and a growing business for Central American coastal communities. While the blue whales at the Central American Dome often stay far enough offshore not to be easily accessible for whale watching, the same population migrates closer to shore in the waters off Mexico and California. Both the United States and Mexico have a long and well-established whale watching industry, which has been ongoing since the 1950s, and which revolves around multiple whale species, including blue whales (Hoyt, 2009B; Hoyt and Iníguez, 2008). While figures related to the economic value of watching blue whales are not available, some examples can be provided. One tourism operation which runs trips specifically focused on blue whales charges US $2,195 per person for a seven day, boat-based trip in the Channel Islands and US$1,995 for a 5-day trip in Baja (http://www.greywhale.com/blue.htm). Whale watching in the Channel Islands is thought to generate US$2 million annually in revenue, a figure that is based on trips to view gray, blue, minke and humpback whales (Pendleton, 2005). In Mexico, where most whale watching is based on the Pacific coast, and in particular Baja, 169,904 whale watching visitors in 2006 spent approximately US$9 million in direct expenditures and US$85.5 million in total expenditures to go whale watching for multiple species (Hoyt and Iníguez, 2008). Boat-based whale watching in California likely generates on the order of US$20 million in gross revenues annually and net revenues of between US$4 million and US$9 million (Pendleton, 2005).

The Central American Dome helps maintain genetic diversity

Relatively little is known about the genetic diversity of oceanic microbial and planktonic communities in the waters of the Central American Dome. The potential for discovery of new species, genes and adaptations exists in this area, as in many ocean areas, and can be of great interest to biotechnology. Upwelling regions are generally dominated by diatom blooms, but the Central American Dome is unique in that it is dominated by the cyanobacteria Synechococcus, the densities of which at the Central American Dome are among the highest reported in nature (Saito et al, 2005). Bacteria and other micro-organisms in this distinctive regime are largely uncharacterized, although preliminary work suggests that Alteromonas and Pseudoalteromonas are the most highly represented groups among bacteria (Krey, 2008). A brief search of the World Intellectual Property Organization patent databases shows that these organisms alone have been the basis of hundreds of patents, and thus are of interest to biotechnology. Much still remains unknown about the diversity of the microbial community in the Central American Dome, and its role in functioning and overall resilience of the ecosystem. It is not surprising that evidence suggests that important discoveries remain to be made (Krey, 2008). This remains true for oceans in general. A recent study (Yooseph et al., 2007) reports the discovery of thousands of new genes and proteins in just a few litres of water, promising many potential new functions.

The Central American Dome is an important area for scientific research

The Central American Dome has been an area of interest for scientific research since 1948 (Wyrtki, 1964) and has been a subject of study in the years thereafter due to its productive tuna fishery (Fiedler, 2002). More recently, the Dome has yielded new scientific information about the behaviour and life history characteristics of blue whales (Mate et al, 1999, Bailey et al, 2009, Matteson, 2009) and the jumbo flying squid (Waluda and Rodhouse, 2006). Currently, the Dome is subject of interest due to its highly productive nature and the oceanographic characteristics that foster this productivity, as well as its role in global geochemical cycling, including carbon cycling and the maintenance of the Earth's climate (Fiedler, 2002; Westberry et al, 2008; Kahru et al, 2007). Full biodiversity surveys of the Central American Dome still remain to be undertaken (Fiedler, 2002), and it is likely that such work would lead to new discoveries about the diversity of micro-organisms and other species at the Dome, as well as the role of those species in the structure and function of the ecosystem (Krey, 2008).

5. The Central American Dome is threatened and in need of management, with current threats including noise disturbance and collision risk to cetaceans and marine turtles from commercial shipping, as well as impacts of fishing, including in particular bycatch risks for leatherbacks, other marine turtles and cetaceans. The impacts of climate change on the Central American Dome are largely unknown, but may include alteration of physical oceanographic processes and/or the migration and distribution patters of species utilizing the area. These threats imply the need for future management action.

Species utilizing the Central American Dome are vulnerable to impacts from commercial shipping

The Central American Dome ranks as an area of medium high impact in a recent global analysis of human impacts on marine ecosystems (Halpern et al, 2008) and human activities may impact it in a variety of ways. One of the growing threats is commercial shipping and its impacts on cetaceans and marine turtles.

Over the past 50 years the size of the global commercial shipping fleet has almost tripled while the total gross tonnage has increased by a factor of six (Hildebrand, 2009). In terms of the volume of cargo transported by sea, this has been approximately doubling every 20 years (http://www.marisec.org/shippingfacts/worldtrade/volume-worldtrade-sea.php). The Central American Dome is located in one of the busiest shipping lanes in the world, with shipping traffic expected to grow in the future with the expansion of the Panama Canal. Figure 12 below, created using online data from the National Center for Ecological Analysis and Synthesis and the University of Santa Barbara illustrates the high intensity of commercial shipping traversing the Dome on its way from the Panama Canal to locations in the north.

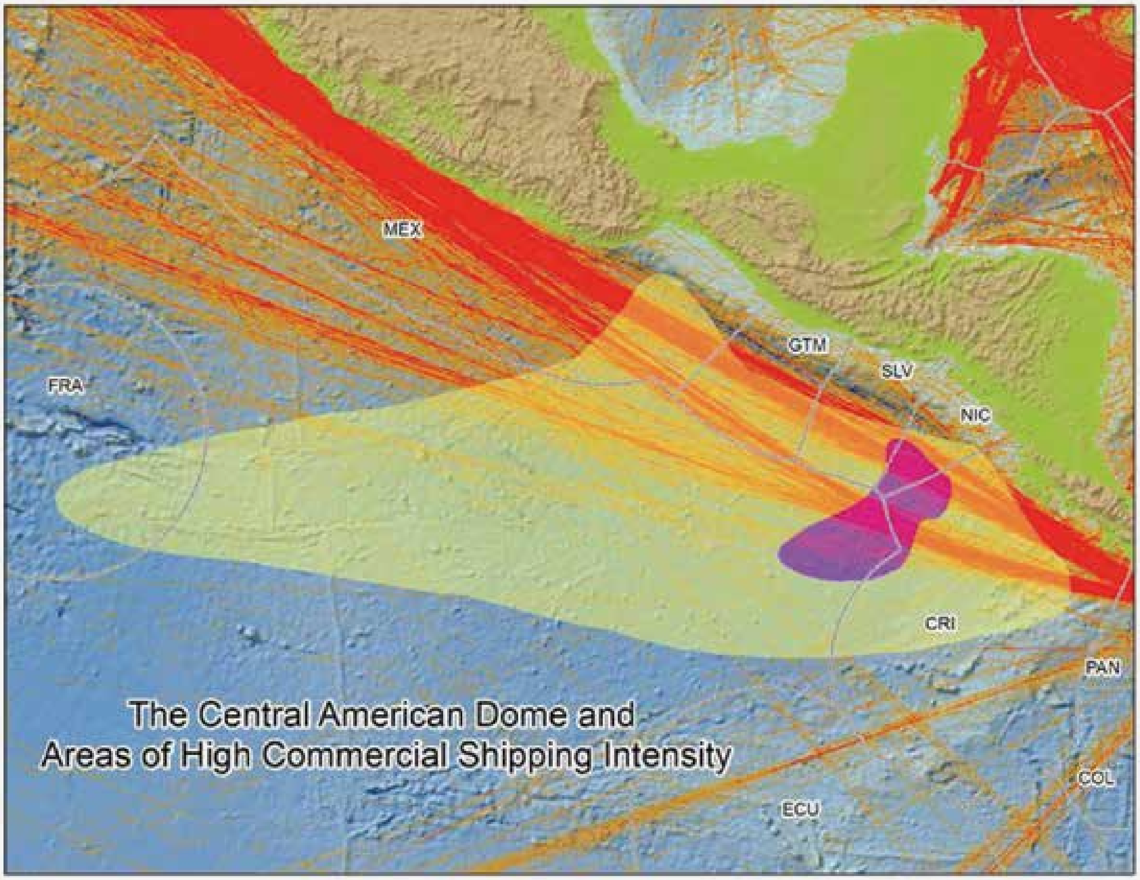

Figure 12: High commercial shipping intensity in the Central American Dome. Lines in red colour indicate highest intensity traffic. Data from the National Center for Ecological Analysis and Synthesis and the University of Santa Barbara.

Potential impacts of commercial shipping on whales and marine turtles include collisions with ships and, for cetaceans, noise from shipping traffic. These impacts may lead to displacement, behavioural disturbance and interference of communication. Physical injury from collision may potentially affect reproductive fitness and may lead to mortality (Laist et al, 2001; Panigada et al, 2008; Hildebrand, 2005; OSPAR Commission, 2009).

Given the large volume of ship traffic transiting through the Central American Dome, there is a risk of collision with whales and turtles. Collisions may have the potential to impede the recovery of the Eastern North Pacific blue whale population if sufficient number of individuals in the population lose reproductive fitness or are mortally injured. While all types of vessels may collide with whales, the injuries are likely to be more severe, or even lethal, when collisions occur with larger or faster vessels (Laist et al, 2001; Vanderlaan and Taggart, 2007), and there are recorded incidences of blue whale mortalities from collisions (Laist et al, 2001). Because the Dome is an area where whales mate, breed, calve and raise calves, it may be particularly vulnerable to shipping. Studies have shown that collisions with calves may be more likely because they spend more time at the surface, are slower, or may need to learn to avoid vessels *(Laist et al, 2001).*

Marine turtles, including leatherback turtles, breathe air and spend much of their time near the sea surface. They may be particularly vulnerable to ship strikes due to their large size and habit of feeding and basking on the sea surface. At the

Central American Dome, leatherback turtle migration corridors are intersected by shipping lanes, placing them at risk from large vessel traffic. Ship strikes have become a major marine turtle conservation challenge worldwide (Panigada et al, 2008), which may in some cases be mitigated by slowing ship speeds *(Hazel et al 2007).*

Noise from shipping may also be a problem for blue whales and other cetaceans, and can, depending on its intensity, frequency and duration, result in hearing impairment, masking of vocalisations and distribution and behaviour changes. Large commercial vessels produce relatively loud and predominately low-frequency sounds (Arveson and Vendittis, 2000, Heitmeyer et al, 2004, NRC, 2003), which are a dominant source of radiated underwater noise at frequencies <200 HZ (Ross, 1976). Marine animals that use low frequencies for hearing and communication, including baleen whales, such as blue whales, seals and sea lions, are most affected by shipping noise (Richardson et al, 1995). Ships generally produce stronger noise when larger or travelling at higher speeds (Hildebrand, 2009). Shipping noise is also expected to be more predominant along shipping lanes or near marinas and ports.

The term masking refers to occasions when increased levels of background or ambient noise reduce an animal's ability to detect relevant sound (Hildebrand, 2005). For marine mammals, relevant sound includes acoustic signals for communication, echolocation or of the marine environment. If the anthropogenic noise is strong enough relative to the received signal, then the signal will be 'masked' (Richardson et al, 1995). There is the potential for permanent damage to hearing from sustained and/or repeated exposure to shipping noise over long periods (OSPAR Commission, 2009). Masking in the marine environment is a regarded as a key concern for marine mammals, especially for those that communicate using low frequencies. A study off California has shown that blue whales increase calling due to shipping noise, indicating that it affects their communication (Melcón et al, 2012). Prolonged disturbance of marine mammals to intermittent or continuous anthropogenic noise has the potential to induce a state of chronic stress if the exposures are of sufficient intensity, duration and frequency.

The impacts of noise on marine animals also depend on the context of exposure. For example, animals may be more sensitive to sound during critical times, such as when they are feeding, breeding, spawning, nursing or rearing young (Tasker et al, 2010; Richardson and Würsig, 1997; Bejder et al, 2009). Because all of these behaviours occur at the Central American Dome, it may be an area where blue whales are more vulnerable to the impacts of sound. Behavioural responses may range from changes in surfacing rates and breathing patterns to active avoidance or escape from the region of highest sound levels. Repeated short-term changes in behaviour may lead to long-term impacts at the population level, through continual avoidance leading to habitat displacement (Lusseau, 2005; Bejder et al, 2006) or by reducing energy acquisition in terms of lost feeding opportunities (Williams et al, 2006). The displacement of numerous cetacean species has been well documented in the scientific literature (Weilgart, 2007; Nowacek et al, 2007).

Marine turtles may also be vulnerable to increased noise in the ocean. Long-term exposure to high levels of low frequency anthropogenic noise in coastal areas that are also vital habitat may affect turtle behaviour and ecology (Samuel, 2005). Avoidance behaviour may result in significant changes in turtle distribution with potential consequences for individuals or populations if displaced from their preferred feeding habitat (Pendoley, 1997). At lower sound levels, turtles that remain in an affected area may show abnormal behaviour that reduces their foraging efficiency. However there are currently no reported studies of the long-term effects of altered behaviour in marine turtles.

The potential impacts of sound also need to be considered in a wider context, through addressing the consequences of acoustic disturbance on populations in conjunction with other stress factors, such as by-catch mortality, overfishing leading to reduced prey availability, and other forms of pollution, such as persistent organic pollutants (Perrin et al, 2002; Read et al, 2006). These various stressors may also act synergistically or cumulatively. For example, underwater noise could interact with by-catch or collision issues in that the individual is less able to detect the presence of fishing nets or nearby vessels (Weilgart, 2007).

Species utilizing the Central American Dome are vulnerable to fisheries impacts, particularly as by-catch

The most important fisheries species in the Eastern Pacific Ocean are the scombrids (Family *Scombridae*), which include tunas, bonitos, and mackerels (IATTC, 2009). The distribution of tuna in the Eastern Tropical Pacific is related closely to areas of upwelling (Hofmann et al, 1981), and it is not surprising that the Central American Dome is one of the four areas in the Eastern Pacific Ocean with the highest potential for finding yellowfin tuna (de Anda-Montañez, 2002). In addition, a strong and shallow thermocline has been correlated with the success of the yellowfin fishery based on an association with dolphins (Green, 1967). Au and Perryman (1985) hypothesized that a shallow thermocline may constrain yellowfin tuna to the surface layer, thereby promoting potential associations with dolphins.

While some uncertainties related to life history and ecological variables, as well as future regime shifts in productivity remain, yellowfin tuna is at the present time estimated to be below but close to levels that would produce maximum sustainable yield (Maunder and Harley, 2006; IATTC, 2012). Of greater cause of concern may be the limited information that exists about the amount and type of by-catch taken by tuna fishing fleets. Fisheries for tunas capture a variety of by-catch, depending on the method of fishing used. The majority of tuna catch in the Eastern Pacific Ocean is taken by longlines and purse seines. The purse-seine method can be divided into three set types: that on tunas associated with floating objects, that on tunas associated with dolphins, and that on free-swimming schools of tunas (Maunder and Harley, 2006).

Marine mammals, especially spotted dolphins (*Stenella attenuata*), spinner dolphins (*S. longirostris*), and common dolphins (*Delphinus delphis*), are frequently found associated with yellowfin tuna in the Eastern Pacific Ocean. The Central American Dome is significant for short-beaked common dolphins (Balance et al, 2006). Short-beaked common dolphins appear to prefer "upwelling-modified" water (Au and Perryman, 1985; Reilly and Fiedler, 1994), and these types of species–habitat relationships appear to remain relatively stable over time (Balance et al, 2006). Purse-seine fishermen have found that their catches of yellowfin can be maximized by setting their nets around herds of dolphins and the associated schools of tunas, and then releasing the dolphins while retaining the tunas. While incidental mortality of dolphins in this operation was high during the early years of the fishery, it seems that measures taken to reduce by-catch have allowed dolphin populations to recover, or, in the case of the short-beaked common dolphin, to stay stable. The estimated dolphin mortality in the Eastern Pacific Ocean yellowfin tuna fishery in 2011 was 986 individuals (IATTC, 2009, 2012). The issue of dolphin by-catch remains on the agenda of the IATTC.

There is less available information relating to marine turtles as by-catch in longline fisheries in The Eastern Pacific Ocean, or, specifically at the Central American Dome. Fisheries by-catch is cited as one of the two main reasons (the other one being egg harvest on nesting beaches) for the more than 90% decline in leatherback turtle nesting populations in the eastern Pacific (IAC, 2012; Santidrián Tomillo et al. 2007; Sarti Martínez et al. 2007). Sea turtles are caught on longlines when they take the bait on hooks, are snagged accidentally by hooks, or are entangled in the lines.

Estimates of incidental mortality of turtles due to longline and gillnet fishing are few. At the 4th meeting of the IATTC Working Group on Bycatch in January 2004, it was reported that 166 leatherback and 6,000 other turtle species, mostly olive Ridley (*Lepidochelys olivacea*), were incidentally caught by Japan's longline fishery in the Eastern Pacific Ocean during 2000, and that, of these, 25 and 3,000, respectively, were dead. At the 6th meeting of the Working Group in February 2007, it was reported that the Spanish longline fleet targeting swordfish in the EPO averaged 65 interactions and 8 mortalities per million hooks during 1990-2005. The mortality rates due to longlining in the Eastern Pacific Ocean are likely to be similar for other fleets targeting bigeye tuna, and possibly greater for those that set their lines at shallower depths for albacore and swordfish. About 23 million of the 200 million hooks set each year in the Eastern Pacific Ocean by distant-water longline vessels target swordfish with shallow longlines. In addition, there is a sizeable fleet of artisanal longline vessels that fish for tunas, billfishes, sharks, and dorado (*Coryphaena spp.*) (IATTC, 2009 and 2012). While these reports provide some information related to individual fleets, comprehensive data on turtle by-catch is still lacking.

A new study (Roe *et al.* 2013, in review) identified an area of moderate by-catch risk along the primary leatherback migration corridor between Costa Rica and the Galapagos Islands. However, this by-catch risk represents a chronic threat during a critical phase in the life cycle of reproductive adult turtles. Bycatch within this region is likely to occur seasonally along defined bathymetric features such as the Cocos Ridge.

The IATCC is collaborating with the Inter-American Convention for the Protection and Conservation of Sea Turtles (IAC) through a Memorandum of Understanding. A report submitted by the IAC (2012) to the IATTC noted the fact that turtle movements are concentrated in well-defined areas in which they are highly susceptible to spatially-explicit anthropogenic threats. The waters included within the defined high-use internesting area should be targets for reducing interactions between fishing gears and leatherbacks during internesting periods. Their report underscores the potential high value of a time-area closure mechanism to reduce at-sea impacts (IAC, 2012). As described earlier in this document, a multi-year satellite telemetry study of adult female leatherbacks in the area by Shillinger et al. 2010 has allowed clear delineation of high-use habitats in the internesting areas and high-seas migratory routes and feeding areas (Shillinger et al., 2008, Shillinger et al. 2011). These data provide good resolution on the time and spacing of leatherback movements during the internesting period, thus offering unique opportunities for fisheries managers to design and implement fishery-appropriate measures to reduce interactions between leatherbacks and fishing gears (IAC, 2012).

While by-catch remains a major issue to be addressed, other fisheries-related threats may also require consideration. Sea turtles, at times, become entangled in the webbing under fish aggregating devices (FADs) and drown. Turtles, whales and

other animals may also become entangled in the fishing gear and be injured or killed.
The fishery for jumbo flying squid at the Central American Dome is based on jigging, and is thus highly selective. The extent of adverse effects on ecosystems from the squid fishery, are unknown. However, as with any large extraction of resources from a system, changes in community structure are likely. The abundance of this species is marked by large fluctuations and large catches can occur only during times of peak abundance. Accordingly, it is difficult to predict the system response to large catches. The loss of fishing gear from squid fisheries may also have an adverse effect, although the extent of that effect has not been explored.

The Central American Dome may be threatened by climate change

While the Central American Dome varies in extent and location annually, it is a persistent and predictable feature, supporting high biological productivity. The oceanographic feature itself may be impacted in the future by climate change, but further research using climate models is required to better understand the character and magnitude of such impacts. Global climate models predict that warming will cause ocean production to decrease at mid-latitudes and low latitudes due to intensified stratification (Behrenfeld *et al,* 2006). However, it is not clear whether and how such global models apply to a single ocean feature, such as the Central American Dome. Any alteration to productivity due to climate change may cause a shift in the abundances of foundation species such as plankton (Vilchis et al, 2009), impacting the entire food web. On the level of species, climate change may affect distribution, migration and health. For example, climate change is expected to cause changes in migratory timing and destinations, population range, breeding schedule, reproductive success and survival of baleen whales, including blue whales (Robinson *et al,* 2009; McLeod, 2009). Marine species, including blue whales, marine turtles and fishes may also be affected through changes in distribution and abundance of their prey (Nicol *et al,* 2008; Simmonds and Isaac, 2007; Saba *et al.* 2007; Saba *et al.,* 2012). Short-lived species, such as squid, may undergo large and rapid fluctuations in population size due to changes in their environment.

For leatherback turtles, the greatest climate change impacts may well occur on nesting beaches (Santidrian *et al.,* 2012) and be associated with sea level rise and rising temperatures. Climate change may also impact ocean currents and circulation, which are important for the dispersal of hatchlings and for the navigation and long-distance migration of adult turtles. While climate change impacts on ocean currents are likely, the nature of these changes, and hence their effects on Leatherbacks, remain uncertain (IUCN, 2009).

Conclusions

This Case for Support document has set out many reasons for the global importance and values of the Central American Dome. It has shown that the Dome is an area of high biological productivity that supports commercially important tunas and squid populations, and provides habitat for dolphins, as well as endangered species, including blue whales and leatherback turtles. The Case for Support document has also shown the importance of the Dome to global carbon cycling, fisheries, tourism, and to scientific research, present and future. Taken together, the Central American Dome is vitally important to the countries of the region, and to the world at large.

Preventing degradation of the Central American Dome as habitat for the many species it supports requires urgent attention to be paid to addressing the various threats that impact upon it. Addressing these threats will require regional collaboration and international consensus and actions to directly target particular threats, but in addition to these, precaution should play a major role in determining appropriate activities. This Case for Support document is a contribution to the process leading to international recognition, management and protection of the Central American Dome. It will be supported by more detailed information, as well as by future engagement with regional neighbors, governments, competent international organizations, , the public, appropriate expert communities and other stakeholders.

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