XIX-63 Insular Pacific-Hawaiian: LME #10

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The Insular Pacific-Hawaiian LME includes a range of islands, atolls, islets, reefs and banks extending 1,500 miles from the Main Hawaiian Islands (MHI) of Hawaii, Maui, Lanai, Molokai, Oahu, Kauai and Nihau to the outer Northwest Hawaiian Islands (NWHI) from Nihoa to Kure Atoll and their near-shore boundaries. The LME has an area of about one million km², of which 35.59% is protected, and contains 0.38% and 1.00% of the world's coral reefs and sea mounts, respectively, and four major estuaries (Sea Around Us 2007). Equatorial currents and predominant northeasterly trade winds influence the region, which has a tropical climate. Sea surface temperature (SST) ranges from 21 - 29^{o} C, with the LME area-averaged SST ranging between 24.5 and 25.3 ^{o} C. The Hawaiian Islands were formed by successive periods of volcanic activity, and are surrounded by coral reefs. More information on environmental conditions influencing the Hawaiian Islands (climate, temperature, salinity, waves, currents and tides) can be found in the Ocean Atlas of the University of Hawaii. NOAA's Western Pacific Region includes the Hawaiian Islands and the U.S. affiliated islands of American Samoa, Guam and the Northern Marianas (NMFS 1999). Book chapters and articles pertaining to this LME include Morgan (1989).

I. Productivity

NOAA's Climate Studies Group has investigated decadal-scale changes in ecosystem-wide productivity in the Northwestern Hawaiian Islands (NWHI), the 1,500 km chain of islands reefs and atolls that stretches northwest of the main Hawaiian Islands (MHI). In the late 1980s a change in ocean conditions and ocean productivity occurred along the NWHI. The effects were seen at several trophic levels, from seabirds and monk seals to reef fishes and spiny lobsters. The Aleutian Low Pressure System was more intense and located more to the south as compared with 1977 - 1988. As conditions changed in the mid-1980s the winter storm winds weakened, resulting in lower vertical mixing, fewer nutrients in the photic zone, and thus reduced productivity in the open ocean (Pacific Fisheries Environmental Laboratory (**PFEL)** online at www.pfeg.noaa.gov).

The Insular Pacific-Hawaiian LME is considered a Class III, low productivity ecosystem (<150 $gCm^{-2}yr^{-1}$). It has a high diversity of marine species but relatively low sustainable yields due to limited ocean nutrients (NMFS 1999). The LME has a high percentage of endemic species: about 18% - 25% of its shore fishes, molluscs, polychaete worms, seastars and algae exist only in this LME. It is a major habitat for the North Pacific humpback whale. The algal habitats and coral reef ecosystems are used by a variety of organisms for food, shelter and nursery grounds. A study of coral disease in this LME, a collaborative effort among the Hawaii Institute of Marine Biology, USGS, the Hawaii Department of Land and Natural Resources Division of Aquatic Resources and the Bishop Museum, is available at the University of Hawaii website. The US National Assessment of Climate Change Overview of Islands in the Caribbean and the Pacific (2000) outlines potential effects of climate change on freshwater resources, public health, ecosystems, biodiversity and sea-level variability.

Oceanic fronts: This is the only mid-ocean LME (Belkin et al., 2009). Meteorological and oceanographic conditions are relatively uniform and can be characterised as subtropical. This relative uniformity is interrupted by the Subtropical Front (STF) that cuts across the LME at 25°-26°N in winter and 28°-29°N in summer (Figure XIX-63.1). This seasonal shift of the STF is caused by a corresponding meridional shift of the wind field convergence, which is ultimately responsible for the STF formation. The STF sometimes consists of two nearly parallel fronts a few degrees of latitude apart that form the double Subtropical Frontal Zone, similar to the double frontal zones found in other subtropical oceans (Belkin 1988, 1993, 1995, Belkin and Gordon 1996, Belkin *et al*. 1998). The STF plays an important role in ocean ecology as it defines a major trans-ocean migration path and feeding ground of various fish species, including apex predators such as tuna, and also turtles (e.g., loggerheads).

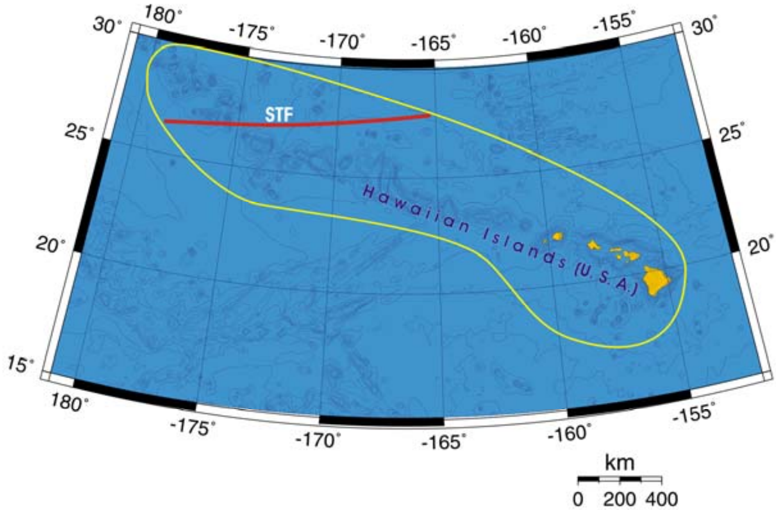

Figure XIX-63.1. Fronts of the Insular Pacific-Hawaiian LME. STF, Subtropical Front. This front is shown with a single line: on many occasions the STF appears as a double front zone (STFZ), with two nearly parallel fronts, North STF and South STF, 300-500 km apart (Belkin 1995; Belkin et al., 1998). Yellow line, LME boundary. After Belkin et al. 2009.

Insular Pacific-Hawaiian LME SST **(Belkin 2009)**
Linear SST trend since 1957: 0.03°C.
Linear SST trend since 1982: 0.45°C.

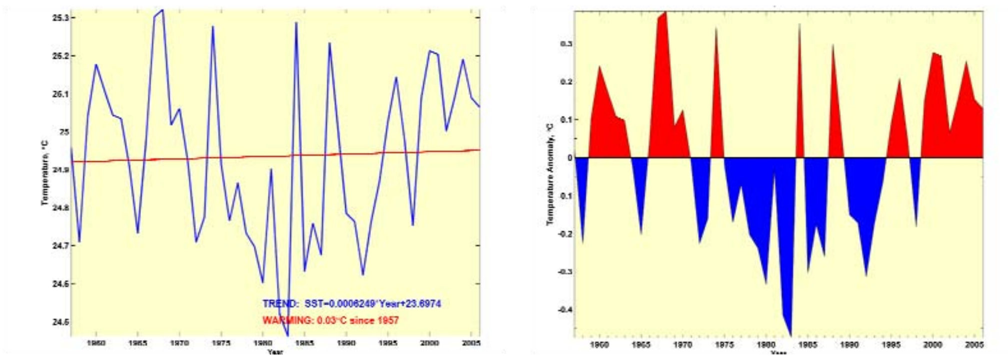

Figure XIX-63.1. Insular Pacific-Hawaiian LME annual mean SST and SST anomaly (right), 1957-2006, based on Hadley climatology. After Belkin 2009.

The Hawaiian LME is a relatively stable oceanic environment within a large-scale anticyclonic subtropical gyre. This stability leads to the most striking feature of the Hawaiian SST time series: the lack of significant long-term warming over the last 50 years. Indeed, linear trend warming since 1957 was only 0.03°C. However, after the minimum observed in 1982-83, the SST rose significantly: the linear trend warming since 1982 was 0.45°C. Interannual variability is not substantial in absolute terms, usually <0.5°C. The LME area-averaged annual SST varies little from one year to another, usually <0.5°C. However, in some locations, interannual variability may be of a larger order of magnitude: in the northern Hawaiian islands, interannual variations up to 8.0°C have been recorded. The relative long-term thermal stability of the Hawaiian LME is confirmed by the *in situ* monitoring data from the Hawaii Ocean Time-Series (HOT) station off Hawaii, which monitors productivity and biomass variables.

Insular Pacific-Hawaiian Chlorophyll and Primary Productivity: The Insular Pacific-Hawaiian LME is considered a Class III, low productivity ecosystem (<150 $gCm^{-2}yr^{-1}$).

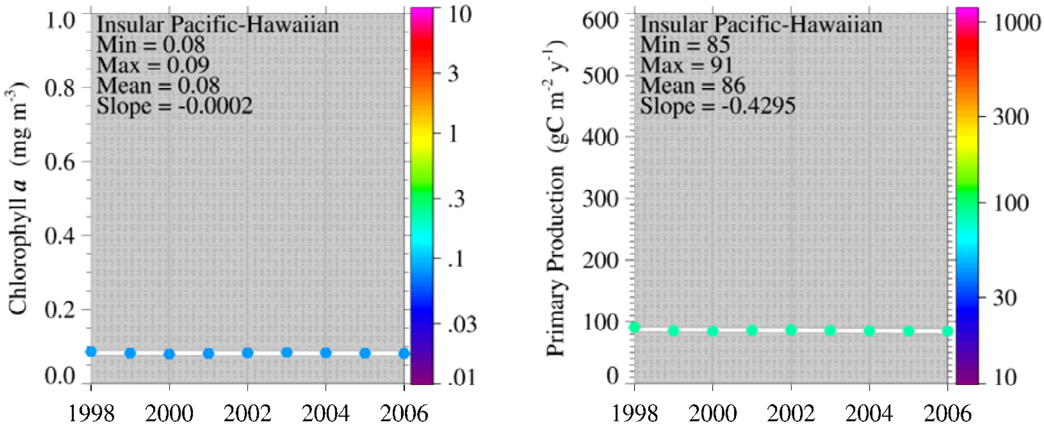

Figure XIX-63.3. Insular Pacific-Hawaiian LME trends in chlorophyll *a* (left) and primary productivity (right), 1998 to 2006, from satellite ocean colour imagery. Values are colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume.

II. Fish and Fisheries

The LME supports a variety of fisheries in both the NWHI and the MHI. The resources include invertebrates, precious coral, bottomfish, armorhead fisheries, highly migratory pelagic fisheries, and nearshore fisheries. The fisheries are on a relatively small scale compared to mainland U.S. fisheries (NMFS 1999). Most fisheries (bottomfish, nearshore reef fish, and invertebrates) are concentrated in the coastal waters of the narrow shelf areas surrounding the islands, except for the fishery for highly migratory pelagic species (NMFS 1999). Tuna (bigeye, yellowfin, skipjack, and albacore) is the LME's most valuable resource. Transboundary fishery resources are of value to the Pacific Rim nations and to the U.S. fleets fishing within and beyond the U.S. EEZ.

The lobster fishery harvests both spiny and slipper lobsters in the NWHI and MHI, and is governed by the Western pacific Regional Fishery Management Council under a Fisheries Management Plan (FMP). Spiny lobster is the primary target of a commercial lobster trap fishery in the NWHI and a small scale, primarily recreational fishery in the MHI (NMFS 2009). Evidence that slipper lobsters have taken over certain areas previously defined as spiny lobster habitats might indicate an increase in abundance and spatial distribution of slipper lobsters due to the "fishing down" of spiny lobsters and the availability of lobster habitat formerly occupied by spiny lobster. Statistics for 1983-1997 showed a decline in lobster landings which is attributed to the combined effect of a shift in oceanographic conditions affecting recruitment and fishing mortality in the mid-1980s

(NMFS 1999). In response to the continuing decline in CPUE the fishery was closed in 1993 and the fishing seasons were shortened in 1994 and 1995. An FMP was implemented in 1983, with amendments designed to eliminate lobster trap interactions with the endangered Hawaiian monk seal (EPA 2004). Other invertebrates harvested are shrimp, squid, and octopus. Precious deepwater corals including pink, gold and bamboo are harvested with set quotas. Black coral is a shallow water species. Bottomfish landings and CPUE have declined since 1948 (NMFS 1999). To determine whether the causes are environmental, biotic (e.g., habitat and competition), or anthropogenic requires more catch data, assessments and research. Bottomfish fisheries (snappers, jacks, and grouper) employ full time fishermen on relatively large vessels in the NWHI. Bottomfish fisheries are managed jointly by the Western Pacific Fishery Management Council and state authorities and are presently overfished. Armorhead fisheries are targeted in the numerous seamounts of the LME, described in Kitchingman et al. 2007, and were exploited in the late 1960s and 1970s by Japanese trawlers and by trawlers from the components of the ex-USSR (especially Russia). Partial estimates of pelagic armorhead (*Pseudopentaceros wheeleri*) and alfonsin (*Beryx* spp.) catches are presented in Zeller et al. (2005). For the present account, they were estimated from the catch of seamount species reported to FAO by Japan and the components of the ex-USSR (Zeller and Rizzo 2007), and from the distribution of seamounts in that LME (from the global seamount map in Kitchingman and Lai 2004).

An issue for the armorhead seamount fishery is how to implement a form of international management that is conducive to stock recovery. Reports on Hawaiian pelagic fisheries (tuna, albacore, marlin, swordfish, dolphinfish and sharks) and gear types are available at NOAA's Pacific Islands Fisheries Science Center website (www.pifsc.noaa.gov). Tropical tunas and dolphinfish are important to subsistence fisheries. Others, especially marlins, yellowfin tuna, and albacore, support important recreational fisheries, as in Kona, Hawaii. Nearshore fisheries are defined as those coastal and estuarine species found in the 0-3 nautical mile zone of coastal state waters. The more highly populated islands receive the heaviest inshore fishing pressure (NMFS 2009). Total reported landings in this LME reached 100,000 tonnes in 1973, when the seamount fishery was at its peak, but have since declined to 5,000 tonnes in 2004 (Figure XIX-63.4).

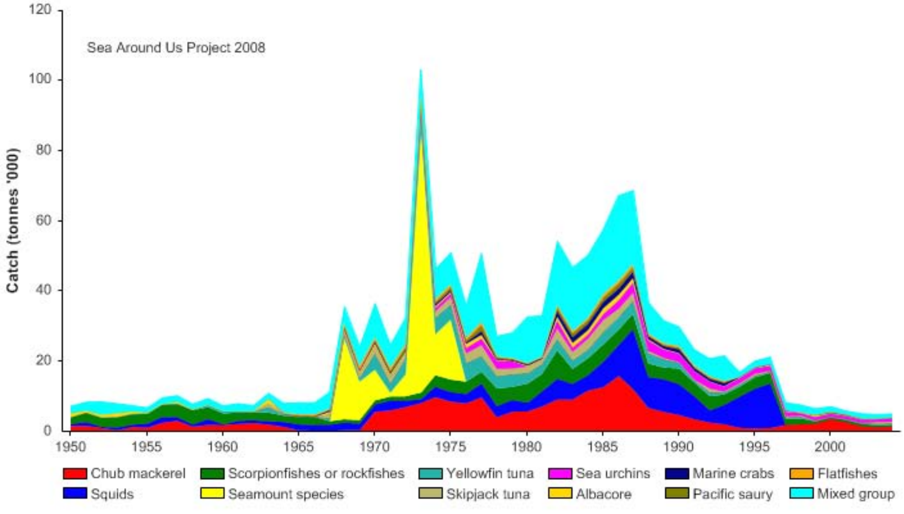

Figure XIX-63.4. Total reported landings in the Insular Pacific-Hawaiian LME by species (Sea Around Us 2007).

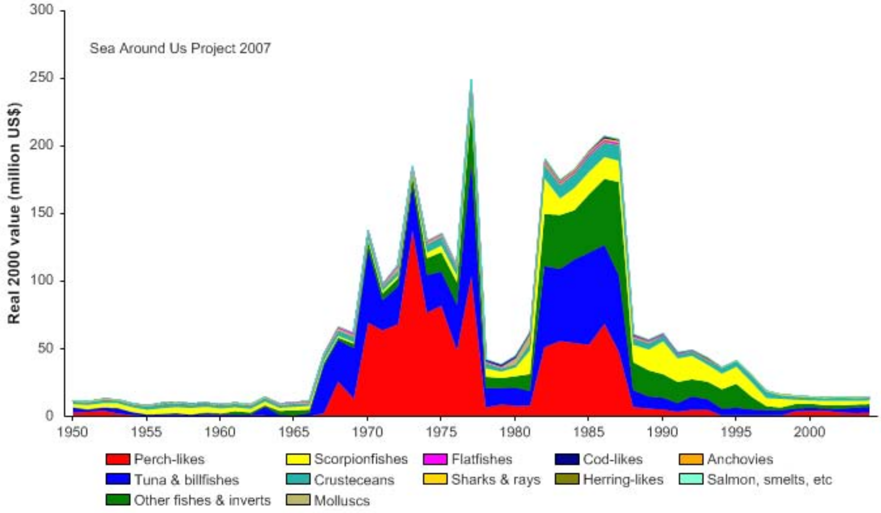

Figure XIX-63.5. Value of reported landings in the Insular Pacific-Hawaiian LME by commercial groups (Sea Around Us 2007).

Catches of inshore fish by small-scale and recreational fishery are high, however, and were they to be included in our analysis, the trend in the reported landings would change considerably (Zeller *et al.* 2005, 2007). Some key issues in Hawaiian fisheries are: (l) the management of highly migratory species, (2) shark finning, (3) longline fisheries bycatch of sea turtles, and (4) longline fisheries bycatch of sea birds. Increasingly, climate change is an issue for ecosystem dynamics and fisheries management (Polovina and Haight 1999). Reported landings were valued at near US$ 250 million (in 2000 US dollars) in 1977 and over $US 200 million in 1986 and 1987 (Figure XIX-63.5). The primary production required (Pauly & Christensen 1995) to sustain the reported landings in the LME reached 7% of the observed primary production in the late 1980s, but has declined to below 1% in recent years (Figure XIX-63.6). The USA accounts for the largest share of the ecological footprint in this LME, although a large share by foreign fleets from Japan and South Korea was reported in the 1970s and 1980s.

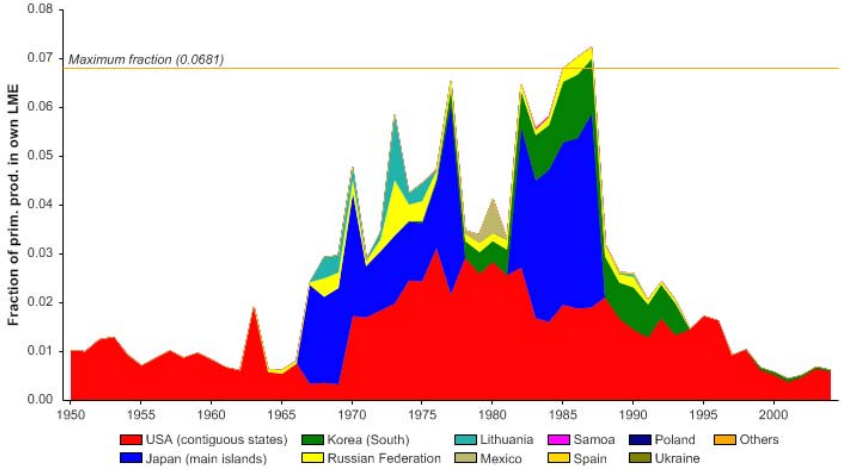

Figure XIX-63.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the Insular Pacific- Hawaiian LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

The mean trophic level of the reported landings (Pauly & Watson 2005) shows a steady decline (Figure XIX-63.7 top), an indication of a ‘fishing down’ of the food web in the LME (Pauly *et al*. 1998). The Fishing-in-Balance (FiB) index also showed an initial increase, followed by a decline since the late 1980s (Figure XIX-63.7 bottom). The true patterns of these indices, however, are likely masked by the underreporting of catches in the LME (Zeller *et al* 2005, 2007).

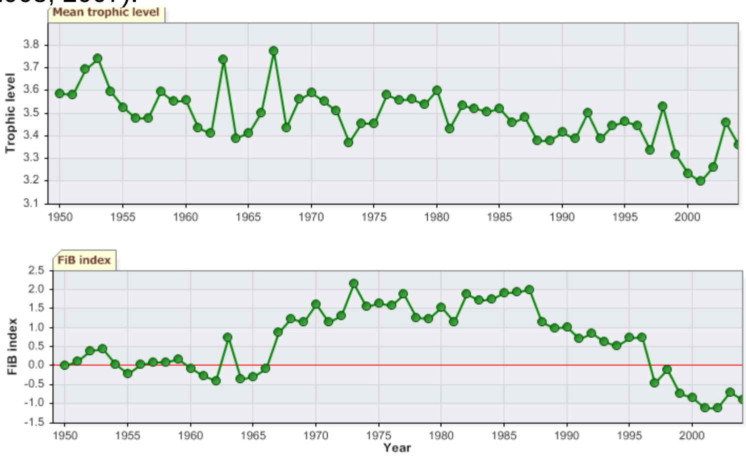

Figure XIX-63.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the Insular Pacific-Hawaiian LME (Sea Around Us 2007).

The problem of misreporting probably also affects the Stock-Catch Status Plots, which indicate that over 80% of commercially exploited stocks have collapsed (Figure XIX-63.8, top), with less than 10% of the reported landings biomass supplied by fully exploited stocks (Figure XIX-63.8 bottom). The US National Marine Fisheries Service (NMFS) includes “overfished” but not “collapsed” in its stock status categories (NMFS 1999). Currently overfished are bottomfish fisheries (snappers, jacks, and grouper).

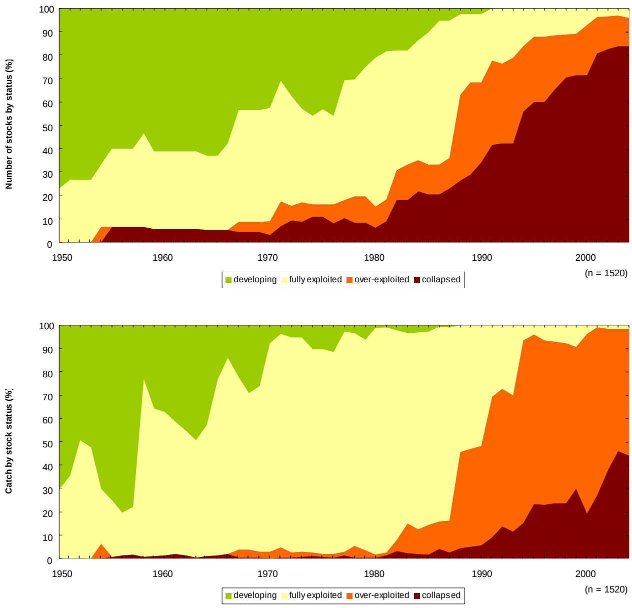

Figure XIX-61.8. Stock-Catch Status Plots for the Insular Pacific-Hawaiian LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number of ‘stocks’, i.e., individual landings time series, only include taxonomic entities at species, genus or family level, i.e., higher and pooled groups have been excluded (see Pauly *et al*, this vol. for definitions).

III. Pollution and Ecosystem Health

Some mangroves have been destroyed to make way for aquaculture (Farewell and Ostrowski 2001. For a chapter on marine mammals of the U.S. Pacific Region and Hawaii, see NMFS (1999). This provides data for Hawaii of the Hawaiian monk seal, and various species of dolphins and whales. Mammals are possible indicators of ecosystem health. For a list of endangered species, see http://hbs.bishopmuseum.org/endangered/. The LME has a high percentage of endemic species and Hawaii has the highest extinction rate of biodiversity of any state in the nation according to the U.S. National Assessment (2000). This LME does not have a comprehensive coastal monitoring programme. Issues needing to be addressed in specific bays are non point source runoff and offshore discharges. The State of Hawaii assessed 99% of its estuarine square miles and 83% of its 1052 miles of shoreline. Fifty-seven percent of Hawaiian estuaries are classified as impaired (EPA 2004). Only 3% of the assessed shorelines are threatened for one or more uses by some form of pollution or habitat degradation (EPA 2001 and 2004). The primary causes of estuarine impairment are increased concentrations of suspended solids and nutrients. For marine pest invasions, see Hutchins et al. 2002. For information on the Kaneohe Bay coral reef system, data on water column and sediments, chlorophyll and nutrients, see www.hawaii.edu/cisnet. Kaneohe Bay is the focus of a long term project initiated in 1998 to monitor water quality and sediment processes as part of a nationwide project cooperatively funded by EPA, NOAA and the National Aeronautics and Space Administration (NASA), termed 'CISNet' (Coastal Intensive Site Network). Recent surveys of the Au'au channel have documented an infestation by the invasive species *Carijoa riisei*, which smothers black coral colonies. The ongoing Hawaii Coral Reef Assessment and Monitoring Programme was created in 1997 by leading coral reef researchers, managers and educators in Hawaii to understand the ecology of Hawaiian coral reefs (http://cramp.wcc.hawaii.edu/). The initial task was to develop a state-wide network of over 30 long-term coral reef monitoring sites, and its associated database. The focus has been expanded to include rapid quantitative assessments and habitat mapping on a state-wide spatial scale. The EPA has developed biological criteria for coral reef ecosystem assessment (Jameson et al 1998). Coral reef ecosystems are biologically critical to this LME and are being impacted by sedimentation, eutrophication and pollution from intensified human activity in some areas. A question needing further study is the effect on fish habitat of the harvesting of precious corals. Some habitat-destructive fishing techniques are coral tangle-netting and dredging.

In addition to unidentified metallic debris buried behind the seawall along most of the northern shore of Tern Island, revealed in the USCG field survey in 1997, elevated levels of PCBs have been detected in the biota around the island (Miao et al., 2001). Elevated levels of copper in crabs, arsenic in eels, and lead in coral were found in the study, suggesting bioaccumulation of those metals. Former military activity in the area did not appear to be a factor in the accumulation of metals, with the possible exception of lead. Teams led by NOAA collected more than 125 tons of debris in the Northwestern Hawaiian Islands in 2004. An estimated 40 tons of marine debris washes up on Hawaiian reefs and beaches each year according to the NOAA Coral Reef Ecosystem Division in Honolulu (www.pifsc.noaa.gov/cred/). Of 87 coastal beaches reporting information to the EPA, only 8% (7 beaches) were closed or under an advisory for any period of time in 2002 (EPA 2004). The Hawaiian Islands are stressed by rapid human population growth, increasing vulnerability to natural disasters, and degradation of natural resources. Droughts and floods are among the climate extremes of most concern as they affect the amount and quality of water supplies in island communities and thus can affect health. Many islands already face chronic water shortages and problems with waste disposal.

IV. Socioeconomic Conditions

The U.S. Census Bureau (http://factfinder.census.gov) estimated the population of Hawaii at 1,285,498 in 2007. A diverse economy provides employment for 610,394 persons in mining, utilities, construction, manufacturing, trade, transportation, information, finance and insurance, real estate, professional scientific and technical services, administration, waste management, education, health care, arts and recreation, food and other services. The Bureau of Labor Statistics (www.bls.gov) estimates that 6,243 of the current labour force works in farming, fishing, and forestry occupations. Tourism is the economic mainstay of Hawaii. The Hawaii Tourism Report (1999) reported that the travel and tourism industry produced an estimated $6.3 billion in 1998. The Hawaii State Department of Business, Economic Development and Tourism (DBEDT) reported that Hawaii received a total of 6,452,834 visitors in 2002 (www.hawaiitourismauthority.org). The people of Hawaii have traditionally used the LME for fishing, aquaculture, trade and transportation. US fishermen have a long history of fishing for Pacific highly migratory species in Hawaii. For the economic contributions of fisheries in Hawaii, see Sharma et al. 1999. Tourism, agriculture, fish processing, financial and other service industries all depend on adequate water supplies. Coral reef ecosystems and fisheries have major cultural and economic importance. Fisheries are partially artisanal and geared towards subsistence while a portion is focused towards large pelagic species for profit. Aquaculture is an important historical activity in the marine environment. The wide range of temperature in the water allows the culture of a wide diversity of species all year: tropical fish, trout, salmon, carp, milkfish, mullet, *mahi mahi*, shrimp, seaweed and shellfish.

V. Governance

This LME is governed by the U.S. and by the State of Hawaii. The Western Pacific Fishery Management Council manages fisheries in the State of Hawaii and in the Territories of American Samoa and Guam, the Commonwealth of the Northern Mariana Islands and US Pacific Islands possessions—an area of nearly 1.5 million square miles (http://www.wpcouncil.org/). Coral reefs are managed under a plan implemented in 1983. The Western Pacific Fisheries Coalition is a partnership between conservationists and fishers to promote the protection and responsible use of marine resources through education and advocacy. For information on the North Pacific Marine Science Organization (PICES), which promotes and coordinates marine research in the northern North Pacific and adjacent seas, see Chapter X - Northwest Pacific. Recent international consultations with Japan, Korea, Russia and the US have begun, to establish new mechanisms for the management of high seas bottom fisheries by vessels operating in the North Western Pacific Ocean. A management concern is the problem of illegal, unreported, and unregulated (IUU) fishing by vessels operating outside the control of regional management regimes (NMFS 2009).

In 2000, President Clinton established the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve. In 2006, President Bush designated the Papahānaumokuākea Marine National Monument, an area larger than all US national parks combined and the second largest area in the world dedicated to the preservation of a unique coral reef area (NMFS 2009). Pacific whales are protected under the International Whaling Commission (IWC), which prohibits non-subsistence hunting by member nations (http://www.iwcoffice.org). With increasing awareness that whales should not be considered apart from their habitat, and that detrimental environmental changes may threaten whale stocks, the IWC decided that the Scientific Committee should give priority to research on the effects of environmental changes on cetaceans. The IWC has adopted Resolutions encouraging the Scientific Committee to increase collaboration and cooperation with governmental, regional and international organisations. Related research will be carried out under the IWC's SOWER programme (www.iwcoffice.org/other/site_map.htm). Humpback whales are classified as an endangered species under the U.S. Endangered Species Act. A Hawaiian Islands Humpback Whale National Marine Sanctuary was designated in 1992 (www.sanctuaries.nos.noaa.gov/oms/omshawaii/omshawaii.html). The Hawaiian Islands National Marine Sanctuary Act aims to protect humpback whales and their habitat within the sanctuary, educate the public, and manage human uses within the sanctuary.

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