

We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,900

Open access books available

186,000

International authors and editors

200M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com



Review of Long Term Macro-Fauna Movement by Multi-Decadal Warming Trends in the Northeastern Pacific

Christian Salvadeo¹, Daniel Lluch-Belda¹,
Salvador Lluch-Cota² and Milena Mercuri¹

¹*Centro Interdisciplinario de Ciencias Marinas del Instituto Politécnico Nacional*

²*Centro de Investigaciones Biológicas del Noroeste*

La Paz, B.C.S.,

Mexico

1. Introduction

Worldwide marine ecosystems are continuously responding to changes in the physical environment at diverse spatial and temporal scales. In addition to the seasonal cycle, other natural patterns occur at the interannual scale, such as El Niño-La Niña Southern Oscillation (ENSO) with a period of about three to five years (Wang & Fiedler, 2006). When ocean conditions stay above or below the long-term average for periods of 10 to 20 years we recognize decadal fluctuations (Mantua et al., 1997), and those with periods longer than 50 years are known as regime (Lluch-Belda et al., 1989). On the ocean, marine populations respond to these variations in different ways, such as changes in their distribution and abundance. Evidence suggests that this multi-decadal scale climate variations are cyclic, which generates recurrent changes in the production level of marine ecosystems in ways that may favor one species or a group over another.

Abrupt changes between multi-decadal phases are known as regime shifts (Overland et al., 2008). The best documented regime shift in the North Pacific occurred in the mid-1970, with strong physical and biological signals, including ocean productivity (Ebbesmeyer, et al., 1991; Roemmich & McGowan, 1995), strong biomass and distribution changes in sardine and anchovy populations (Kawasaki, 1983; Lluch-Belda et al., 1989), and several other fish populations (Beamish et al., 1993; Mantua et al., 1997; Holbrook et al., 1997). These changes impacted marine food webs and ultimately affected the distribution and survival of marine top predators such as seabirds and marine mammals (Trites & Larkin, 1996; Veit et al., 1997; Trites et al., 2007). In this work we review published reports on long term macro-fauna (nekton) movements as related to multi-decadal temperature trends in the Northeastern Pacific.

2. Long term ocean surface variability on the southern California current system

The study area (Fig 1) is under the influence of the California Current System, where, several authors have observed environmental and biological multi-decadal climate signals

(Lluch-Belda et al., 1989; Ware, 1995; Mantua et al., 1997). To describe the environmental conditions on the California Current System, monthly gridded (2x2 degree) sea surface temperatures (from January 1900 to December 2010) were analyzed for the area limited by the 20-42°N latitude and 102-140°W longitude (Fig. 1). The data base is known as “Extended Reconstructed Sea Surface Temperature” and was obtained from the National Oceanic and Atmospheric Administration (NOAA) web site (<http://lwf.ncdc.noaa.gov/oa/climate/research/sst/ersstv3.php>).

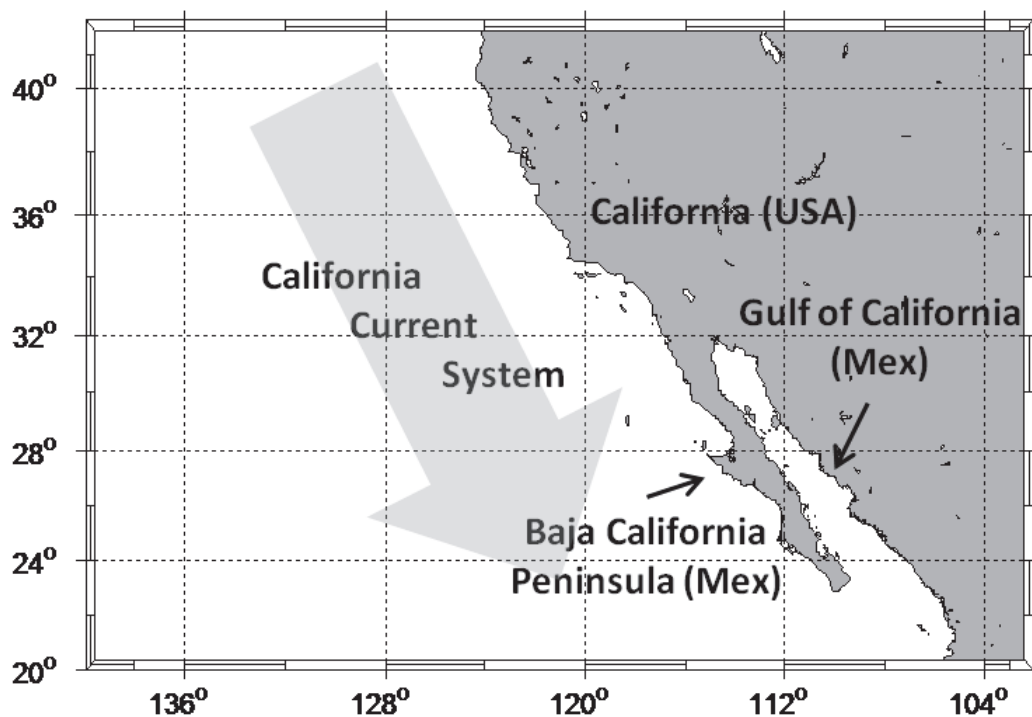


Fig. 1. Study area; USA: United States of America; Mex: Mexico.

To isolate scales of variability from the SST time series, we computed the long term mean and the seasonal signal by fitting annual and semiannual harmonics to the 110-year monthly mean time series (Ripa, 2002). Then we computed SST anomalies as residuals containing sub-seasonal (meso-scale) and low frequency variability (interannual and large scales) after extracting the long term mean and seasonal signals at each grid point. To analyze the regional modes of SST anomalies over the study area (Fig. 1), an empirical orthogonal functions analysis (EOF) was conducted using SST anomalies. The EOF decomposes the variability of the anomalies in a set of N uncorrelated orthogonal functions; each n -function represents an independent “mode of variability” (Björnsson & Venegas, 1997; Venegas, 2001).

The first EOF mode of SST anomalies explains 48% of the total variance over the study area. The spatial pattern shows a typical distribution of a global mode, where the surface temperature increase (decrease) in the whole area at the same time and according to the sign of the EOF time series, which explains up to 50% of the unseasonal SST variability off California and Baja California Peninsula (Fig. 2, upper panel). This mode shows a great interannual and multi-decadal variability in its time series (Fig. 2, lower panel). Two long

warming trends and two long cooling trends are evident. Warming trends occurred between the late 1910s and the end of the 1930s, and from 1975 until the end of the 1990s, while the cooling trend occurred from the beginning of the twentieth century to the late 1910s, and between the early 1940s and 1975. The strong warming event at the end of the 1950s was not considered as a long term trend, because this was caused by the strong El Niño 1958-59 event, and a few years later the SST recovered its cooling trend until 1975. Also, our results suggested a new cooling trend beginning with the new century. The origin of these multi-decadal trends is subject to debate. In this regard, several studies and hypothesis have been developed to explain the physic mechanisms that are underlying this multi-decadal variability, but are not the matter of this work.

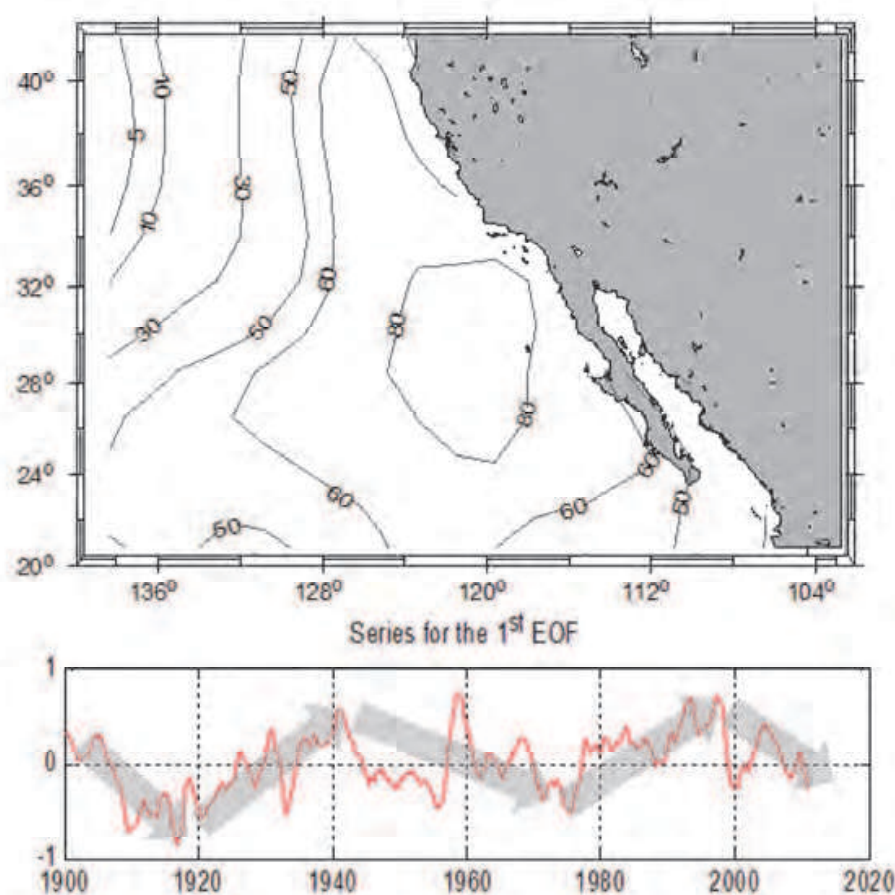


Fig. 2. Local explained variance (%) and temporal patterns of the first EOF mode of SST anomalies.

3. Long term macro-fauna movement

The California sardine (*Sardinops sagax caeruleus*) is the most abundant fish species in the northeast Pacific. It is a key component of the California Current pelagic ecosystem, being the main prey of several pelagic species such as seabirds, marine mammals, predatory fishes and squid (Bakun et al., 2010). This sardine has two core centers of distribution, one in the west coast of the Baja California Peninsula, and the other inside the Gulf of California. From these centers, schools may expand into the surrounding waters when environmental

conditions are suitable. This species tends to have large interannual fluctuations in its abundance, due to strong variations in recruitment related primarily to environmental variability in their spawning areas (Lluch-Belda et al., 1986; Hammann et al., 1998). In addition to these interannual fluctuations, this group has a not yet totally understood regime shift time scale (~60 years) of global alternation between sardine and anchovy populations, due to the expansion and contraction of their populations (Fig. 3; Kawasaki, 1983; Lluch-Belda et al., 1989; Baumgartner et al., 1992; Chavez et al., 2003; Bakun et al., 2010). These can be seen in the commercial landings of California state (USA) waters (Fig. 4) and in fossil records over the last 2000 years (Baumgartner et al., 1992). Chavez et al (2003) related this regime shift to the SST variability in the northeast Pacific. This relationship is evident in the sardine landings (Fig. 4), where increases are evident during warming trends (1920-1940 & 1975-2000) and a decrease during the cooling trend (1940-1975).

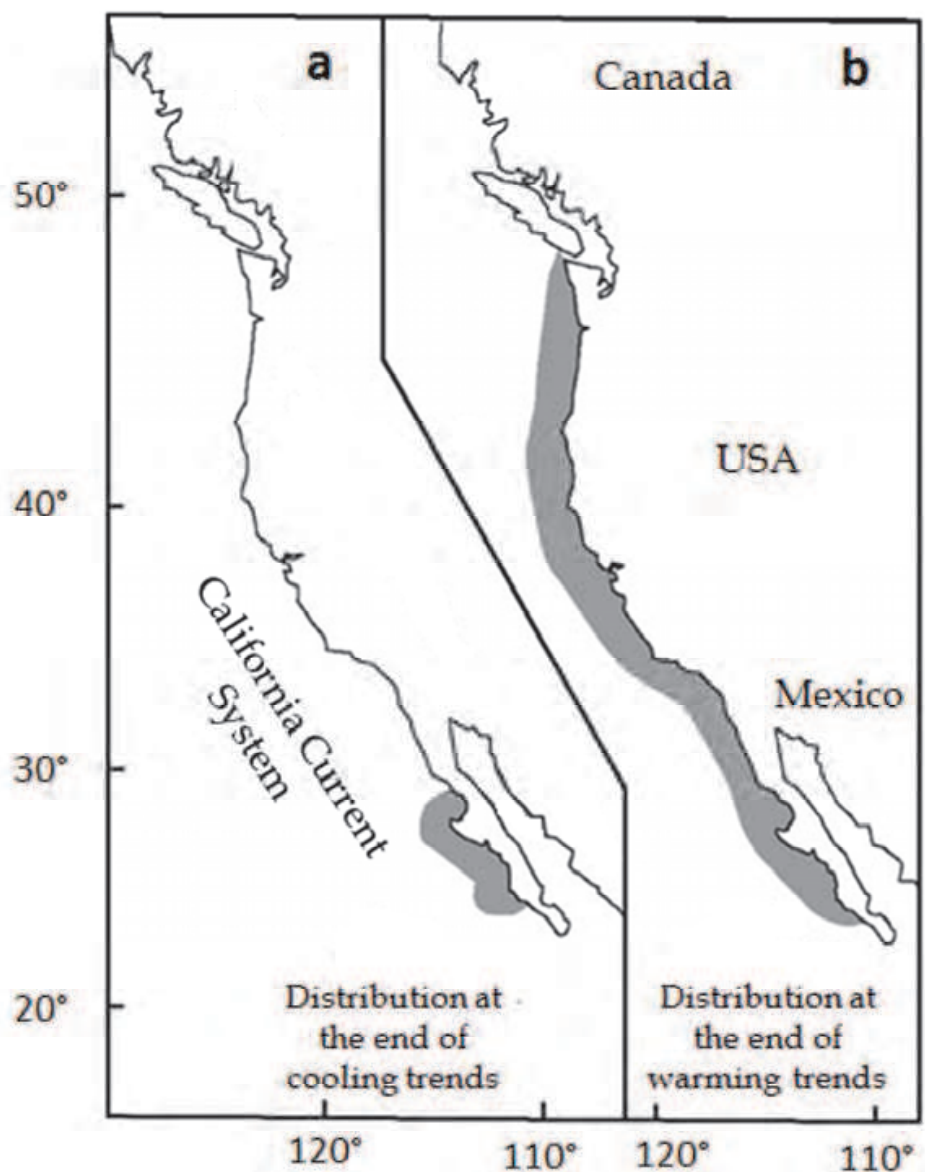


Fig. 3. Contraction (a) and expansion (b) of California sardine populations in the Northeast Pacific at the end of cooling and warming periods respectively (Bakun et al., 2010).

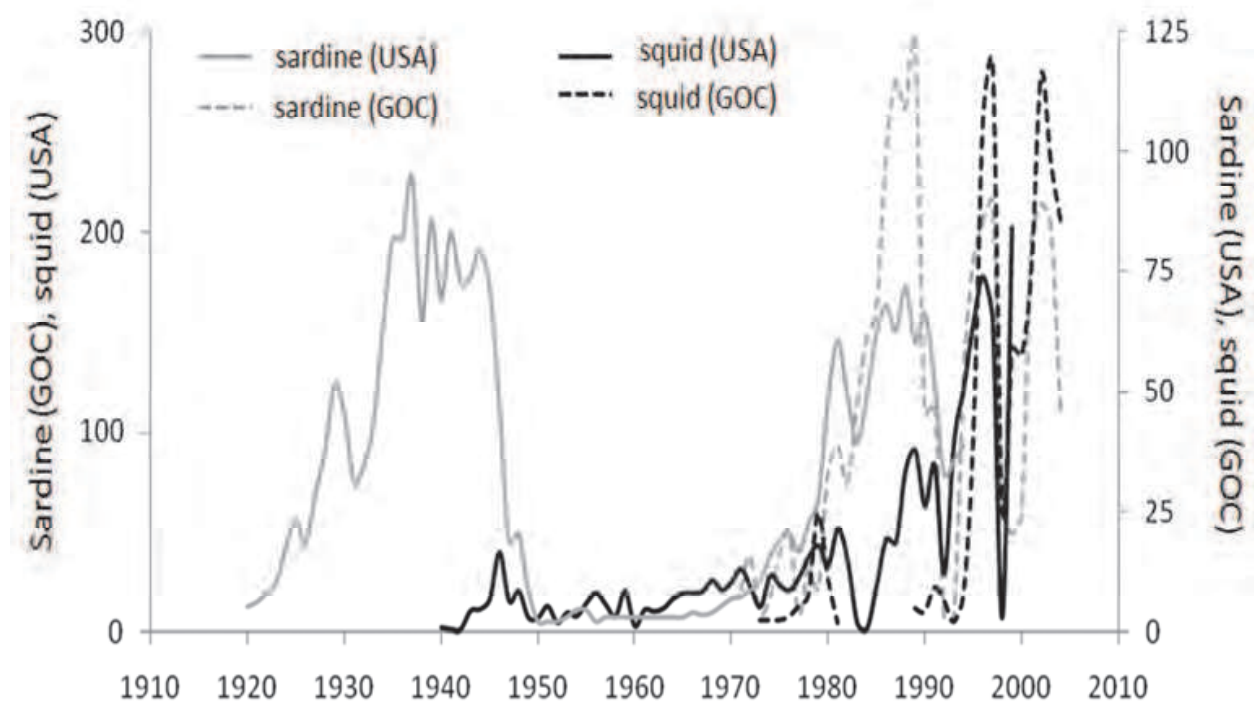


Fig. 4. California sardine landings at California waters (USA; thousands of tons) from FAO (1997), and for Gulf of California waters (GOC; thousands of tons) from SAGARPA; jumbo squid landings at California waters (USA; millions of pounds) from NOAA web page (<http://www.pfeg.noaa.gov/research/climate/marine/cmffish/cmffishery.html>), and Gulf of California (GOC; thousands of tons) from SAGARPA.

The Jumbo squid (*Dosidicus gigas*) is a large ommastrephid (up to 50 kg mass and overall length of 2.5 m) endemic to the Eastern Tropical Pacific. This squid is an important component of the marine food web that prey on small pelagic and mesopelagic fishes, crustaceans and squids (Markaida & Sosa-Nishizaki, 2003; Armendáriz-Villegas, 2005; Field et al., 2007); being an energy transfer from the mesopelagic food web to higher trophic level species as tunas, billfish, sharks, and marine mammals (Galván-Magaña et al., 2006; Field et al., 2007). The jumbo squid maintain the largest squid fishery in the world, which operates off the coasts of Peru, Chile and Central America, and in the Gulf of California (Morales-Bojórquez et al., 2001; Waluda & Rodhouse 2006). Recent scientific publications, anecdotal observations and fisheries landings pointed out a range expansion of jumbo squid throughout the California Current and southern Chile over the past decade (Fig. 4 & 5; Cosgrove, 2005; Chong et al., 2005; Wing, 2006; Zeidberg & Robinson, 2007). This sustained range expansion has generated hypotheses related to changes in climate-linked oceanographic conditions and reduction in their competing top predators (Zeidberg & Robinson, 2007; Waters et al., 2008). However, the coincidence of the recent poleward range expansions in both hemispheres, and the reports of the increases in the abundance off the west coasts of North and South America in the late 30s (Rodhouse, 2008), (just at the end of the 1910-1940 warming trend), suggests a physically-induced forcing mechanism. This may be related with long term warming trends and the poleward expansion of their primary habitat (Bazzino, 2008).

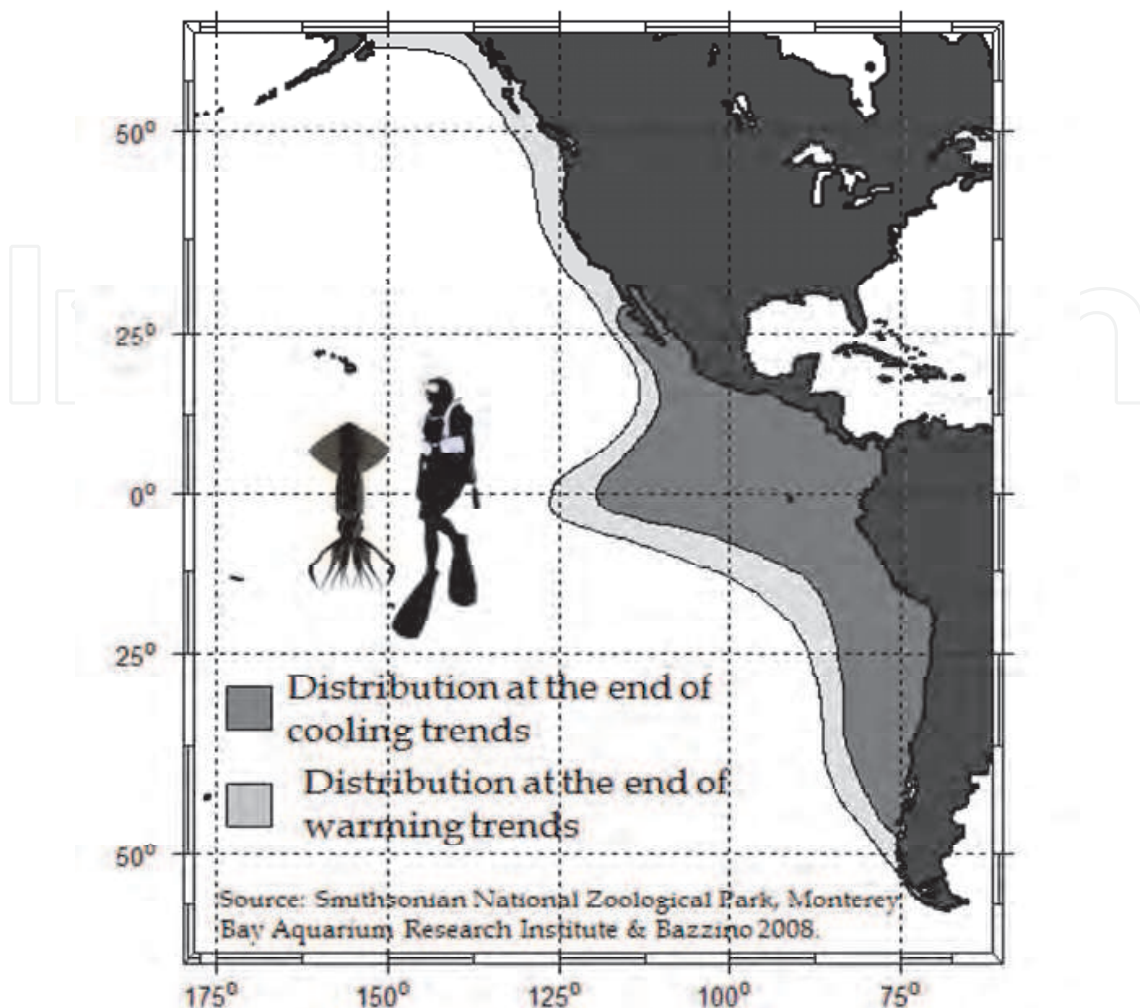


Fig. 5. Jumbo squid expansion during multi-decadal environmental trends.

The sperm whale (*Physeter macrocephalus*) is the largest odontocete, or toothed whale. This predator can be found in all world oceans in deeper waters, feeding largely on epi- and mesopelagic squid species (Whitehead, 2003). Groups of females and immatures are distributed on tropical and temperate waters, while solitary males are distributed on polar waters and only go to lower latitudes to breed. In the California Current System, Barlow & Forney (2007) showed that the abundance of sperm whales is temporally variable, and the two most recent estimates (2001 and 2005) were markedly higher than the estimates for 1991–96. Related to this increased in whales abundance, Jaquet et al. (2003) noted that few sightings of sperm whales were reported during the 1980s along the Baja California Peninsula; then their abundance appeared to increase since 1992. Actually these whales occur into the Gulf of California year-round and the high proportion of mature females and first-year calves suggests that this area is an important breeding and feeding ground for the sperm whale (Jaquet et al., 2003). As sperm whales are known to forage on jumbo squid, these authors coincided that the increased in the presence of sperm whale in both regions could be related with the expansion of jumbo squid in the California Current System and in the Gulf of California during the past two decades. Concurrently, a decrease in sperm whale abundance in the Galapagos Islands since the early 1990s has been observed (Whitehead et al., 1997), as well as animals from Galapagos have been spotted inside the Gulf (Jaquet et al., 2003), suggesting a northward shift in their distribution.

The Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) is an average-sized oceanic dolphin (from 2 to 2.5 m) found in temperate waters of the North Pacific Ocean, feeding on small pelagic and mesopelagic fish and squid. In the eastern Pacific, large groups of this species are frequently seen in the California Current System (Leatherwood et al., 1984; Stacey & Baird, 1990; Keiper et al., 2005). The southern boundary of the distribution of Pacific white-sided dolphins is the Gulf of California, where the species has been observed only in its southwest area during the winter and spring (Aurioles et al., 1989). During the last 3 decades, Salvadeo et al. (2010) documented a decline in the presence of this dolphin species in the southwest Gulf of California, just during the end of the last warming trend in the California Current System (Fig. 2). Considering that the thermal environment is physiologically important to animals, the authors listed three evidences consistent with a poleward shift in their range: 1) The occurrence of this dolphin has decreased by approximately 1 order of magnitude per decade since the 1980s, (Table 1); 2) their monthly contraction to cooler months of the year (Fig. 6); and 3) the occurrence of this dolphin has increased on the west coast of Canada from 1984 to 1998 (Morton, 2000).

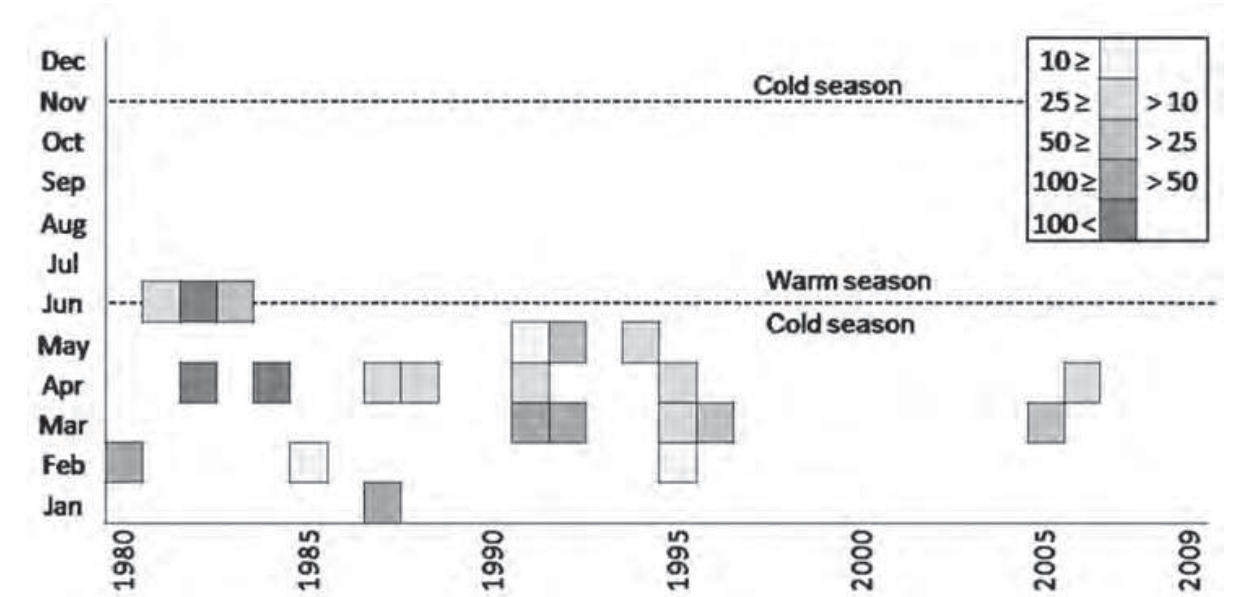


Fig. 6. Historical numbers of animals per month of Pacific white-sided dolphin from the southwest Gulf of California (Salvadeo et al. 2010).

| Period | Effort | Sightings | Animals | Mean | Min. | Max. | SD | Sightings/hrs | Animals/hrs |
|--------|--------|-----------|---------|------|------|------|----|---------------|-------------|
| 1980s | 252 | 10 | 647 | 65 | 2 | 200 | 67 | 0.039 | 2.56 |
| 1990s | 1659 | 16 | 316 | 20 | 1 | 45 | 12 | 0.010 | 0.19 |
| 2000s | 1986 | 2 | 50 | 25 | 20 | 30 | 7 | 0.001 | 0.03 |

Table 1. Pacific white-sided dolphin: accumulated historical data from the southwest Gulf of California for the last 3 decades. Effort (h); sightings: number of occasions when the species was observed; mean, minimum (min.), maximum (max.), and SD for group size; sightings h-1 and animals h-1: abundance relative to effort; 1980s: 1978–1988; 1990s: 1989–1999; 2000s: 2000–2009 (Salvadeo et al., 2010).

The gray whale (*Eschrichtius robustus*) is a medium sized baleen whale reach 14 m in length and weigh of 45 metric tons. Some pods of gray whales breed every boreal winter at three lagoons along the Baja California Peninsula. At the end of the breeding season, the whales migrate to the feeding grounds in the Bering and Chukchi Seas, where they feed on benthic fauna (Rice & Wolman, 1971). The population of gray whales seems to have reached carrying capacity, with population size fluctuating between 20,000 and 22,000 animals (Rugh et al., 2008). As the Pacific white-sided dolphin, the evidences pointed out a possible poleward shift of the gray whale distribution related to the last warming SST trend. These evidences are: 1) there is an apparent long term tendency in the use of breeding lagoons, increasing at the northern lagoon and decreasing at the southern lagoon (Urbán et al., 2003a); 2) the decrease in the numbers of whales at the breeding lagoons during the last years, also observed from shore-based surveys at Piedras Blancas during the northbound migration (Urbán et al., 2010); 3) an increase in calf sightings at California (USA) correlating with warmer sea surface temperature anomalies (Shelden et al., 2004); 4) a range expansion into Arctic waters (Moore and Huntington, 2008); 5) during warming El Niño years the whales tend to use northern areas more intensively than in normal years (Gardner & Chávez-Rosales, 2000; Urbán et al., 2003b); 6) the unusual sighting of a gray whale in the Mediterranean Sea, it is another possible effect of their expansion to the north, which allows them to cross the Arctic to the Atlantic (Scheinin et al., 2011); and 7) in spite of having an increasing population of gray whales in the eastern Pacific, the observations of individuals inside the Gulf of California has been consistently declining (Salvadeo et al., 2011).

4. Conclusions

Two well defined long term climate warming trends were observed in the SST anomalies, these appear to be part of cyclical changes that include cooling trends over the study area (Fig 2). Changes in the SST are indicators of more complex ocean processes related to alterations in oceanic and atmospheric circulations, which ultimately affect the enrichment of superficial waters. The biological responses to those ocean processes are complex and not well understood.

There are evidences which indicate that distribution shifts related to long term ocean warming had occurred for some species, including poleward shifts (gray whale and Pacific white-sided dolphin), range expansions (California sardine and jumbo squid) and redistribution (sperm whale). The distributions of most species are defined by interactions between available environmental conditions and the ecological niches that they occupy on the ecosystem (Macleod, 2009). For gray whales and Pacific white-sided dolphins the cause of their range shift is apparently driven by the importance of thermal environment for the species. This poleward shift caused by thermal niche was also recorded in stranding records of dolphin species in the north-eastern Atlantic Ocean (Macleod et al., 2005). For the sperm whale it seems to be related with a trophic link, because their redistribution appears to be coupled with the range expansion of their primary prey, the jumbo squid. Multi-decadal range shift related with trophic interactions was also observed in the north-eastern Atlantic Ocean, from the subpolar gyre variability via plankton, to marine top predators (Hátún et al., 2009)

For the California sardine and the jumbo squid, their range expansions appear to be related with the extension of suitable habitat for their reproduction and recruitment. These range shifts seems to be cyclical, where their populations retract to subtropical areas during

cooling trends and expand to temperate areas during warming trends. For cetacean species, this cycle was not observed yet, possibly due to the lack of information, so maybe this could also happen. These recurrent populations' changes also were observed on small pelagic fish and squids in other world oceans current systems (Fig. 7), and show the links between multi-decadal global ocean climate variability and regional fish and squid populations (Lluch-Belda et al., 1989; Schwartzlose et al., 1999; Sakurai et al., 2000; Tourre et al., 2007). These synchronous population shifts are consequence of cyclic changes on the environment that affect the production level of marine ecosystems in ways that may favor one species or group of species over another, affecting the marine food web structure and function.

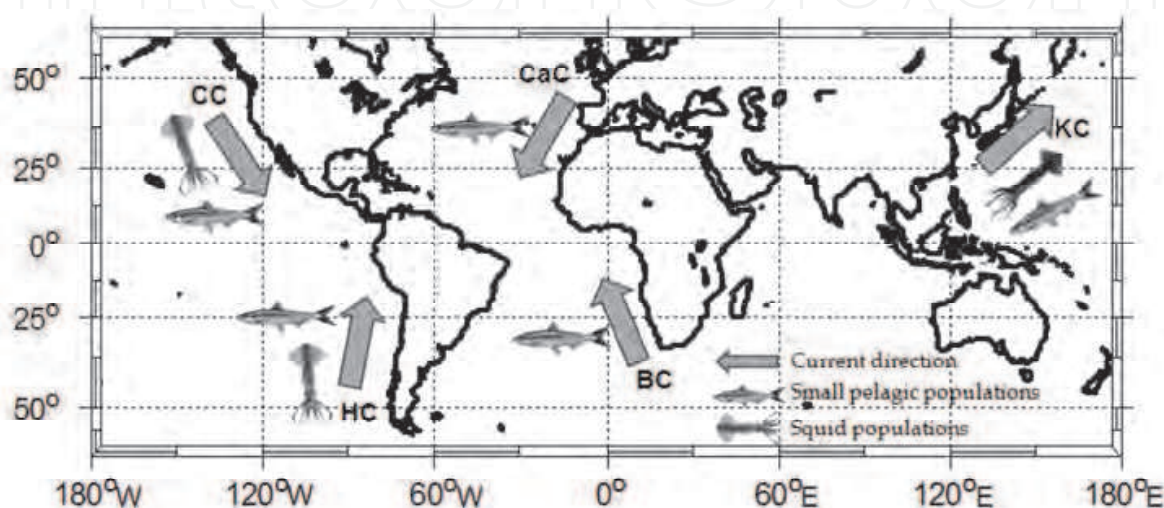


Fig. 7. Oceans current systems, where distribution shift were recorded on small pelagic fish and squid populations; ocean currents: California (CC), Canary (CaC), Kuroshio (KC), Humboldt (HC) and Benguela (BC); source: Lluch-Belda et al., 1989; Schwartzlose et al., 1999; Sakurai et al., 2000; Tourre et al., 2007, Bazzino 2008.

In conclusion, there are evidences that distribution shift occurred for some species due to long term ocean warming. Future scientific studies need to focus on understand the mechanisms of these long term cyclic variations and their effects on marine fauna, and incorporate this knowledge into the management and conservation approaches of the living marine resources.

Finally, the first EOF mode of SST anomalies showed a cooling trend for the last 10 years (Fig. 2). If the observed trends during the past are replicated, we should expect the beginning of a new ecological cycle, forced by climate tendencies that will restrict the distribution of California sardine to the west coast of the Baja California peninsula; and will move the jumbo squid range southward, forcing lower squid population levels at the west coast of the Baja Peninsula and the Gulf of California; related with this, a subsequent movement of sperm whales to other areas of the Pacific would occur, and the return of white-sided dolphins and gray whales as seasonal visitors of the Gulf of California.

5. Acknowledgment

We acknowledge the Consejo Nacional de Ciencia y Tecnología (CONACyT) and the Programa Institucional de Formación de Investigadores from the Instituto Politécnico

Nacional (PIFI-IPN) for the scholarships given to C.S. This work was done under the project “Patrones de cambio climático en el océano y sus efectos ecológicos”, financed by “SEP-CONACyT”. We also thank Emilio Beier for his help in the SST analysis, and Dr. German Ponce with the SEMARNAT-CONACYT project No 108270 for his support for the publication of this chapter.

6. References

- Armendáriz-Villegas, J. (2005). Hábitos alimenticios del Calamar Gigante (*Dosidicus gigas*; Orbigny, 1835), en el Centro del Golfo de California durante los años 2002 y 2003, Bachelor Thesis, Universidad Autónoma de Baja California Sur, La Paz, B.C.S., México
- Aurioles D. G., Gallo-Reynoso J. P., Muñoz E. L. & Ejido J. V. (1989). El delfín de costados blancos (*Lagenorhynchus obliquidens*, Gill 1865) (Cetacea: Delphinidae) residente estacional en el suroeste del Golfo de California, México. *Anales del Instituto de Biología, Universidad Nacional Autónoma de México, Serie Zoología* Vol.60, pp.459–472, ISSN 0368-8720
- Bakun, A., Babcock, E. A., Lluch-Cota, S. E., Santora, C. & Salvadeo C. J. (2010). Issues of ecosystem-based management of forage fisheries in “open” non-stationary ecosystems: the example of the sardine fishery in the Gulf of California. *Reviews in Fish Biology and Fisheries* Vol.20, No.1, pp. 9-29. ISSN 1573-5184
- Barlow, J. & Forney K. A. (2007). Abundance and density of cetaceans in the California Current ecosystem. *Fishery Bulletin* Vol.105, pp. 509–526. ISSN 0090-0656
- Baumgartner, T. R., Soutar, A. & Ferreira-Bartrina V. (1992). Reconstruction of the history of Pacific sardine and Northern Pacific anchovy populations over the past two millennia from sediments of the Santa Barbara basin. *CalCOFI Reports* Vol.33, pp. 24-40. ISSN 0575-3317
- Bazzino, G. (2008). Estructura poblacional, movimientos horizontales y migraciones verticales del calamar gigante en el Golfo de California y en el Océano Pacífico frente a la Península de Baja California. PhD. Thesis, Centro de Investigaciones Biológicas del Noroeste, La Paz, B.C.S., México. 126 pp.
- Beamish, R. J. & Bouillon, D. R. (1993). Pacific salmon production trends in relation to climate. *Canadian Journal of Fisheries and Aquatic Sciences* Vol.50, pp. 1002–1016. ISSN 1205-7533
- Björnsson, H. & Venegas S. A. (1997) A manual for EOF and SVD analyses of climatic data, McGill University, Retrieved from <http://www.geog.mcgill.ca/gec3/wp-content/uploads/2009/03/Report-no.-1997-1.pdf>
- Chavez F. P., Ryan J., Lluch-Cota S. E. & Niquen C. M. (2003). From anchovies to sardines and back: multi-decadal change in the Pacific Ocean. *Science* Vol.299, pp. 217–221. ISSN 1095-9203
- Chong, J., Oyarzun, C., Galleguillos, R., Tarifeño, E., Sepúlveda R. & Ibáñez, C. (2005). Fishery biology parameters of jumbo squid, *Dosidicus gigas* (Orbigny, 1835) (Cephalopoda: Ommastrephidae), in Central Chile coast (29°S–40°S) during 1993–1994. *Gayana* Vol.69, No.2, pp. 319–328. ISSN 0717-652X
- Cosgrove, J. A. (2005). The first specimens of Humboldt squid in British Columbia. *PICES Press* Vol.13, No.2, pp. 30–31. ISSN 1195-2512

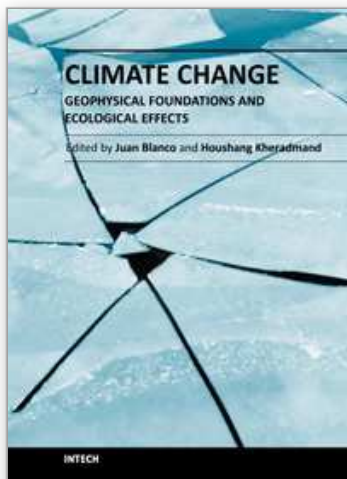
- Ebbesmeyer, C. C., Cayan, D. R., McLain, D. R., Nichols, F. H., Peterson, D. H. & Redmond K. T. (1991). 1976 step in the Pacific climate: forty environmental changes between 1968-1975 and 1977-1984. Seventh annual Pacific climate (PACCLIM) workshop, Asilomar, California, USA, April 1990
- FAO. (1997). Review of the state of world fishery resources: marine fisheries. FAO Fisheries Circular No.920 FIRM/C920, ISSN 0429-9329, Rome, Italy.
- Field, J. C., Baltz, K., Phillips, A. J. & Walker, W. A. (2007). Range expansion and trophic interactions of the jumbo squid, *Dosidicus gigas*, in the California Current. CalCOFI Reports Vol.48, pp. 131-146. ISSN 0575-3317
- Galván-Magaña, F., Olson, R. J., Bocanegra-Castillo, N. & Alatorre-Ramirez, V G. (2006). Cephalopod prey of the apex predator guild in the epipelagic eastern Pacific Ocean In: The role of squid in open ocean ecosystems, Olson, R. J. & Young, J. W. (Eds.), pp. 45-48, GLOBEC international project, ISSN 1066-7881, Honolulu, Hawaii, USA
- Gardner, S. C. & Chávez-Rosales, S. (2000). Changes in the relative abundance and distribution of gray whales (*Eschrichtius robustus*) in Magdalena Bay, Mexico during an El Niño event. Marine Mammal Science Vol.16, pp. 728-738, ISSN 0824-0469
- Hammann M. G., Nevárez-Martínez M. O. & Green-Ruiz, Y. (1998). Spawning habitat of the Pacific sardine (*Sardinops sagax*) in the Gulf of California: Egg and larval distribution 1956-1957 and 1971-1991. CalCOFI Reports Vol.39, pp. 169-179, ISSN 0575-3317
- Hátún, H., Payne, M. R., Beaugrand, G., Reid, P. C., Sandø A. B., Drange, H., Hansen, B, Jacobsen, J. A. & Bloch D. (2009). Large bio-geographical shifts in the north-eastern Atlantic Ocean: From the subpolar gyre, via plankton, to blue whiting and pilot whales. Progress in Oceanography Vol.80, pp. 149-162, ISSN 0079-6611
- Holbrook, S., Schmitt, R. & Stephens, J. (1997) Changes In An Assemblage of Temperate Reef Fishes Associated With A Climate Shift. Ecological Applications Vol.7, pp. 1299-1310, ISSN 1051-0761
- Jaquet, N., Gendron, D. & Coakes, A. (2003). sperm whales in the gulf of California: residency, movements, behavior, and the possible influence of variation in food supply. Marine Mammals Science Vol.19, No.3, pp.545-562, ISSN 0824-0469
- Kawasaki, T. (1983). Why do some pelagic fishes have wide fluctuations in their numbers? - biological basis of fluctuation from the viewpoint of evolutionary ecology, In: Reports of the Expert Consultation to Examine Changes in Abundance and Species Composition of Neritic Fish Resources. Sharp, G. D. & Csirke J. (eds.), pp. 1065-1080, FAO Vol.91, No.2-3, Rome, Italy
- Keiper, C. A., Ainley, D. G., Allen, S. G. & Harvey J. T. (2005). Marine mammal occurrence and ocean climate off central California, 1986 to 1994 and 1997 to 1999. Marine Ecology Progress Series Vol.289, pp. 285-306. ISSN 1616-1599
- Leatherwood, S., Reeves, R. R., Bowles, A. E., Stewart, B. S. & Goodrich, K. R. (1984). Distribution, seasonal movements and abundance of Pacific white-sided dolphins in the eastern North Pacific. Science Report Whales Research Institute Vol.35, pp. 129-157
- Lluch-Belda, D., Magallón, B. F. J. & Schwartzlose, R. A. (1986). Large fluctuations in the sardine fishery in the Gulf of California: possible causes. CalCOFI Reports Vol.27, pp. 136-140, ISSN 0575-3317

- Lluch-Belda, D., Crawford R. J. M., Kawasaki, T., MacCall, A. D., Parrish, R. H., Schwartzlose, R. A. & Smith P. E. (1989). Worldwide fluctuations of sardine and anchovy stocks: the regime problem. *South Africa Journal of Marine Science* Vol.8, pp. 195-205, ISSN 1814-2338
- MacLeod, C. D. (2009) Global climate change, range changes and potential implications for the conservation of marine cetaceans: a review and synthesis. *Endangered Species Research* Vol.7, pp. 125-136, ISSN 1613-4796
- MacLeod, C. D., Bannon, S. M., Pierce, G. J., Schweder, C., Learmonth, J. A., Reid, R.J. & Herman, J. S. (2005) Climate change and the cetacean community of northwest Scotland. *Biological Conservation* Vol.124, pp. 477-483, ISSN 0006-3207
- Mantua, N. J., S. R. Hare, Y. Zhang, J. M. Wallace, and R. C. Francis. 1997. A Pacific decadal climate oscillation with impacts on salmon. *Bulletin of the American Meteorological Society* Vol.78, pp. 1069-1079, ISSN 0003-0007
- Markaida U, Sosa-Nishizaki O (2003) Food and feeding habits of jumbo squid *Dosidicus gigas* (Cephalopoda: Ommastrephidae) from the Gulf of California, Mexico. *Journal of the Marine Biological Association of the United Kingdom* Vol.83, pp. 507-522, ISSN 0025- 3154
- Moore, S. E., & Huntington, H. P. (2008). Arctic marine mammals and climate change: impacts and resilience. *Ecological Applications* Vol.18, pp. 157-165, ISSN 1051-0761
- Morales-Bojórquez, E., Cisneros-Mata, M. A., Nevarez-Martínez, M. O. & Hernández-Herrera, A. (2001). Review of stock assessment and fishery biology of *Dosidicus gigas* in the Gulf of California, Mexico. *Fisheries Research* Vol.54, pp. 83-94, ISSN 0165-7836
- Morton, A. (2000). Occurrence, photo-identification and prey of Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) in the Broughton Archipelago, Canada 1984-1998. *Marine Mammals Science* Vol.16, pp. 80-93, ISSN 0824-0469
- Overland, J., Rodionov, S., Minobe, S., & Bond, N. (2008). North Pacific regime shifts: Definitions, issues and recent transitions. *Progress In Oceanography* Vol.77, No.2-3, pp. 92-102, ISSN 0079-6611
- Rice, D. W., & Wolman, A. A. (1971). The life history and ecology of the gray whale (*Eschrichtius robustus*). *American Society of Mammalogists, Special Publication* No.3 Stillwater, Oklahoma, USA
- Ripa, P. (2002). Least squares data fitting. *Ciencias Marinas* Vol.28, pp.79-105,ISSN: 0185-3880
- Roemmich, D. & McGowan, J. (1995). Climate warming and the decline of zooplankton in the California Current. *Science* Vol.267, pp. 1324-1326. ISSN 1095-9203
- Rodhouse P. G. (2008). Large-scale range expansion and variability in ommastrephid squid populations: a review of environmental links. *CalCOFI Reports* Vol.49, pp. 83-89, ISSN 0575-3317
- Rugh, D. J., Breiwick, J., Muto, M. M., Hobbs, R. C., Sheldon, K. W., D'Vincent, C., Laursen, I. M., Rief, S. L., Maher, S. L., & Nilson, S. D. (2008). Report of the 2006-2007 census of the eastern North Pacific stock of gray whales. Alaska Fisheries Science Center, Retrieved from www.afsc.noaa.gov/Publications/ProcRpt/PR2008-03.pdf
- Sakurai, Y., Kiyofui, H., Saitoh, S., Goto, T. & Hiyama, Y. (2000). Changes in inferred spawning areas of *Todarodes pacificus* (Cephalopoda: Ommastrephidae) due to

- changing environmental conditions. ICES Journal of Marine Science Vol.57, pp. 24-30, ISSN 1095-9289
- Salvadeo C. J., Lluch-Belda, D., Gómez-Gallardo, A., Urbán-Ramírez, J. & MacLeod, C. D. (2010). Climate change and a poleward shift in the distribution of the Pacific white-sided dolphin in the northeastern Pacific. *Endangered Species Research* Vol.11, pp. 13-19, ISSN 1613-4796
- Salvadeo C. J., Lluch-Cota, S., Maravilla-Chavez, M. O., Alvarez-Castañeda S. T., Mercuri, M. & Ortega-Rubio, A. (2011). Impact of climate change on gray whale populations, whale watching, and conservation. *Conservation Science Symposium*, Loreto, BCS, Mexico, May 25-28, 2011
- Scheinin, A. P., Kerem, D., MacLeod, C. D., Gazo, M., Chicote C. A. & Castellote, M. (2011). Gray whale (*Eschrichtius robustus*) in the Mediterranean Sea: anomalous event or early sign of climate-driven distribution change?. *Marine Biodiversity Records* Vol.4, e28, ISSN 1755-2672
- Schwartzlose, R. A., Alheit, J., Bakun, A., Baumgartner, T. R., Cloete, R., Crawford, R. J. M., Fletcher, W. J., Green-Ruiz, Y., Hagen, E., Kawasaki, T., Lluch-Belda, D., Lluch-Cota, S., MacCall, A. D., Matsuura, Y., Nevarez-Martinez, M. O., Parrish, R. H., Roy, C., Serra, R., Shust, K. V., Ward, M. N. & Zuzunaga, J. Z. (1999). Worldwide large-scale fluctuations of sardine and anchovy populations. *South Africa Journal of Marine Science*, Vol.21, pp. 289-347, ISSN 1814-2338
- Shelden, K. W., Rugh, D. J., & Schulman-Janiger, A. (2004). Gray whales born north of Mexico: indicator of recovery or consequence of regime shift? *Ecological Applications* Vol.14, pp. 1789-1805, ISSN 1051-0761
- Stacey, P. J. & Baird, R. W. (1990). Status of the white-sided dolphin, *Lagenorhynchus obliquidens*, in Canada. *Canadian Field-Naturalist* Vol.105, pp. 219-232, ISSN 0008-3550
- Tourre, Y. M., Lluch-Cota, S. E. & White, W. B. (2007). Global multi-decadal ocean climate and small-pelagic fish population. *Environmental Research Letters* Vol.2, doi:10.1088/1748-9326/2/3/034005, ISSN 1748-9326
- Trites, A. W. & Larkin, P. A. (1996). Changes in the abundance of Steller sea lions (*Eumetopias jubatus*) in Alaska from 1956 to 1992: how many were there? *Aquatic Mammals* Vol.22, pp. 153-166, ISSN 0167-5427
- Trites, A. W., Deecke, V. B., Gregr, E. J., Ford, J. K. B. & Olesiuk P. F. (2007). Killer whales, whaling and sequential megafaunal collapse in the North Pacific: a comparative analysis of dynamics of marine mammals in Alaska and British Columbia following commercial whaling. *Marine Mammal Science* Vol.23, pp. 751-765, ISSN 0824-0469
- Urbán, R. J., Rojas, L. B., Pérez-Cortéz, H., Gómez-Gallardo, A. U., Swartz, S. Ludwig, S. & Brownell, L. (2003a). A review of gray whales on their wintering grounds in Mexican waters. *Journal of Cetacean Research and Management* Vol.5, pp. 281-295, ISSN 1561-0713
- Urbán, R. J., Gómez-Gallardo, U. A. & Ludwig, S. (2003b). Abundance and mortality of gray whales at Laguna San Ignacio, Mexico, during the 1997-98 El Niño and the 1998-99 La Niña. *Geofisica Internacional* Vol.42, pp. 439-446, ISSN 0016-7169
- Urbán, R. J., Gómez-Gallardo U. A., Rojas-Bracho, L. & Swartz S. L. (2010). Historical changes of gray whales abundance in San Ignacio and Ojo de Liebre breeding lagoons, Mexico. *IWC Scientific Committee Paper*, SC/62/BRG36, ISSN-0255-2760

- Venegas S. A. (2001). Statistical methods for signal detection in climate. Danish Center for Earth System Science Report No.2, Retrieved from www.atmos.colostate.edu/~davet/AT655/notes/VenegasNotes.pdf
- Veit, R. R., McGowan, J. A., Ainley, D. G., Wahls, T. R., & Pyle, P. (1997). Apex marine predator declines ninety percent in association with changing oceanic climate. *Global Change Biology* Vol.3, pp. 23–28, ISSN 1365-2486
- Waluda, C. M. & Rodhouse, P. G. (2006). Remotely sensed mesoscale oceanography of the central Eastern Pacific and recruitment variability in *Dosidicus gigas*. *Marine Ecology Progress Series* Vol.310, pp. 25–32. ISSN 1616-1599
- Wang, C. & Fiedler, P. C. (2006). ENSO variability and the eastern tropical Pacific: A review. *Progress in Oceanography* Vol.69: 239-266. ISSN 1369-9350
- Ware, D. M. (1995). A century and a half of change in the climate of the NE Pacific. *Fisheries Oceanography* Vol.4, pp. 267-277, ISSN 1365-2419
- Waters, G. M., Olson, R. J., Field, J. C. & Essington T. E. (2008). Range expansion of the Humboldt squid was not caused by tuna fishing. *PNAS* Vol.105, No.3, E5, ISSN 1091-6490
- Whitehead, H. (2003). "*Sperm Whales: Social Evolution in the Ocean*." University of Chicago Press, ISBN 9780226895178, Chicago USA
- Whitehead, H., Christal, J. & Dufault, S. (1997). Past and distant whaling and the rapid decline of sperm whales off the Galápagos Islands. *Conservation Biology* Vol.11, pp. 1387-1396, ISSN 0888-8892
- Wing, B. L. (2006). Unusual invertebrates and fish observed in the Gulf of Alaska, 2004–2005. *PICES Press* Vol.14, No.2, pp. 26–28
- Zeidberg L. D. and B. H. Robinson. 2007. Invasive range expansion by the Humboldt squid, *Dosidicus gigas*, in the eastern North Pacific. *PNAS* Vol.104, No.31, pp. 12948-12950, ISSN 1091-6490

IntechOpen



Climate Change - Geophysical Foundations and Ecological Effects

Edited by Dr Juan Blanco

ISBN 978-953-307-419-1

Hard cover, 520 pages

Publisher InTech

Published online 12, September, 2011

Published in print edition September, 2011

This book offers an interdisciplinary view of the biophysical issues related to climate change. Climate change is a phenomenon by which the long-term averages of weather events (i.e. temperature, precipitation, wind speed, etc.) that define the climate of a region are not constant but change over time. There have been a series of past periods of climatic change, registered in historical or paleoecological records. In the first section of this book, a series of state-of-the-art research projects explore the biophysical causes for climate change and the techniques currently being used and developed for its detection in several regions of the world. The second section of the book explores the effects that have been reported already on the flora and fauna in different ecosystems around the globe. Among them, the ecosystems and landscapes in arctic and alpine regions are expected to be among the most affected by the change in climate, as they will suffer the more intense changes. The final section of this book explores in detail those issues.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Christian Salvadeo, Daniel Lluch-Belda, Salvador Lluch-Cota and Milena Mercuri (2011). Review of Long Term Macro-Fauna Movement by Multi-Decadal Warming Trends in the Northeastern Pacific, Climate Change - Geophysical Foundations and Ecological Effects, Dr Juan Blanco (Ed.), ISBN: 978-953-307-419-1, InTech, Available from: <http://www.intechopen.com/books/climate-change-geophysical-foundations-and-ecological-effects/review-of-long-term-macro-fauna-movement-by-multi-decadal-warming-trends-in-the-northeastern-pacific>

INTECH
open science | open minds

InTech Europe

University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China

Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821

© 2011 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the [Creative Commons Attribution-NonCommercial-ShareAlike-3.0 License](https://creativecommons.org/licenses/by-nc-sa/3.0/), which permits use, distribution and reproduction for non-commercial purposes, provided the original is properly cited and derivative works building on this content are distributed under the same license.

IntechOpen

IntechOpen