The common denominator is that anchovies and other associated Eastern Boundary Current species thrive on cooler coastal ocean upwelling periods. Sardine and their warmer preferring kin seem to "cope" with these strong upwelling periods by subsisting in small colonies, usually equatorward as well as offshore, just beyond direct influences of lowest temperatures due to coastal upwelling. They await opportunities to recolonize the near shore environments, and to "bloom" during the periods of relatively weaker upwelling associated with lesser along-shore winds and onshore overlay of slightly warmer oceanic conditions.

Longer life cycles and migratory propensities also provide sardine and herring with distributional advantages allowing them to quickly take advantage of any relaxation along the extensive upwelling zones. Similarly, North Sea-Baltic Sea or Newfoundland herrings search from offshore, along coastal habitats (Iles and Sinclair 1982; Alheit and Hagen 1997), to recolonize any locales that fit their requirements. On the other hand, the anchovies and their kin are relegated the shorter term options, of finding local habitats that provide the upwelling intensities, and spawning options which they seem to find along coastlines wherever promontories form eddies. These are often associated with small permanent features such as bays with good tidal flushing and reasonably stable backwater circulation that minimizes anoxia. All the related ocean dynamics are forced from remote climate-driven ocean-atmosphere physics.

There are also arrays of demersal species that are similar "tuned" to these alternative "regimes". Most migratory predators distribution and abundance cycles also reflect the same patterns as their preferred prey species. Still, the most dramatic changes in fisheries production occur in the massive pelagic fisheries of Eastern Boundary Current systems, although virtually all temperate to polar fishery systems exhibit strong variations (c.f. Parrish and MacCall 1978; Iles and Sinclair 1982; Sharp and Csirke 1983; Leggett, Frank and Carscadden 1984; Moser, Smith and Eber 1987; Wyatt and Larrañeta 1988; Baumgartner, Soutar and Ferreira-Bartrina 1992; Hollowed and Wooster 1992; Hollowed, Bailey and Wooster 1995; Beamish and Boulton 1993; Francis and Hare 1994; Hare and Francis 1995; Polovina, Mitchum and Evans 1995; Mantua *et al*. 1997. The very powerful presentation, and follow-up by Kawasaki (1983) and Kawasaki *et al*. (1991) of the Japanese sardine story, and the apparent synchrony of northern hemisphere Pacific sardine population cycles and those of the Humboldt Current stimulated the present era of climate and fisheries research.

4. SOME EXPECTATIONS

Humans and fishes share a long history. The long road to understanding fish reproduction successes, as described above, was a result of concerned researchers attempting to stabilize fisheries production. The one thing that can be certain is that climate will continue to change, and fisheries distributions and abundances will continue to respond as they have in the past (Soutar and Isaacs 1974; Soutar and Crill 1977; Baumgartner *et al*. 1989; Baumgartner, Soutar and Ferreira-Bartrina 1992; Kawasaki *et al*. 1991). Climate prediction is one well-defined objective, although our poor knowledge of the many interactions and complexities described above is still quite limiting. Lots of basic information about fisheries responses related to likely changes are available, i.e. those factors that involve known patterns in environmental change.

What is hoped to have been made clear by this presentation of diverse information resources, and their apparent interrelations is that these environmental changes are neither "random", nor "stochastic" in the parlance of would-be modelers. All are components of a long sequence of patterns and processes that tend to fall into rhythms, and patterns of their own, within the larger and longer time and space scales. The fact that each of the particular patterns or cycles involved is interactive reshapes the sequences such that they create "harmonics" and long epochs with flat trends, as well as sharp spikes. All are, none-the-less, patterned. In particular, transitions from one state to another are forecastable, given the insights and observations that would provide that possibility.

Given the recent centuries' historical regional synchronies, what does not make sense, or likely pose anything very useful for society is for great amounts of effort and resources to be squandered on creating digital simulacra of equilibrium or stability-based population models, or any more attempts to assume "Closed Systems" such as the individual fish populations – or regarding the Earth's atmosphere and surface air temperatures – sans ocean interactions.

The future and hope for credible forecasting of anything beyond persistence time scales requires dynamic interactions be learnt, i.e. observed and understood. The methods now available that seem to offer most useful forecastive results, in the sense of producing pragmatic event and pattern forecasts, are the somewhat more complex phase of information collation and analysis that is referred to as "Pattern Matching". This seems to work when there are clearly defined "System States" or extremes of the sort offered by ENSO "Warm" and "Cold" Events, or the growing climate Indices for large regions of the world's oceans. Although no two ENSO Events seem to ever be really alike, from our very short record sets, at their fullest manifestations, El Niño and La Niña consequences fall into two notably separate distributions, both bringing considerable damage/good to distinctly different regions.

William Gray's annual forecasts (c.f. 1990, 1991 – see also website in annex) of Atlantic and Gulf of Mexico hurricane landings provide a useful example of "Pattern Matching" techniques, as well as successful modern credible approaches to climate/weather forecasting. As well, his continuous monitoring and updates provide valuable corrections, as new interactions and responses factor into the regional information. The more conventional numerical model-based ENSO forecasts offer a hybrid of "digital simulacra" and Pattern Matching that seems to be improving as more information about the internal oceanography is included in the primarily atmosphere dominated models. There have been vast improvements by including ever more diverse observational data within the forecast models, over the "Closed System" digital models of prior research and forecast-modeling epochs. This was predictable, too, as the early generations of computer modelers quickly broke into various "schools" of how to build projection models. The more is known, the better are model projections. The fewer observations that are included in models, the poorer the model output. Of course, there is always the GIGO problem. Without clear connections between cause and effect, using presumed related data sets can be misrepresentative, and entirely misleading.

To date Climate Change research, per se, has been limited to post-hoc explanations in fisheries contexts, due to the recent generations' fisheries managers emphasis on blunted stock assessment tools (c.f. Sharp, Csirke and Garcia 1983; Sharp 1987, 1988, 1991, 1995b, 1997, 2000). Fortunately, there remain active fishery research programs that focus on both physiological ecology and related climate-scale changes ongoing around the world. It is expected that progress will continue, and fisheries forecasts will displace hindcasts as the basis for fisheries resource management.

Impacts of climate change on regional fisheries can be ranked in terms of likelihood (for either warming or cooling) of impacts. Most of this knowledge comes from empirical studies over the recent 50 years, when weather and environmental records became fundamental to explaining individual species' behaviours and population responses to changes in local conditions.

Fisheries most responsive to climatic variables are listed below in descending order of sensitivity:

(a) Freshwater fisheries in small rivers and lakes, in regions with larger temperature and precipitation change.
(b) Fisheries within Exclusive Economic Zones (EEZ), particularly where access-regulation mechanisms artificially reduce the mobility of fishing groups and fleets and their abilities to adjust to fluctuations in stock distribution and abundance.
(c) Fisheries in large rivers and lakes.
(d) Fisheries in estuaries, particularly where there are species sans migration or spawn dispersal paths or in estuaries impacted by sea-level rise or decreased river flow.
(e) High-seas fisheries.

One can quickly see that the larger scale production sea fisheries are not under any direct or immediate threat due to climate changes. The fisheries most sensitive to climate change are also amongst the most affected by human interventions such as dams, diminished access to up- or down-river migrations, filling in of wetlands, and other issues of human population growth and habitat manipulation, particularly expanded agricultural water use and urbanization.

Options are also known for coping that provide large benefits irrespective of climate change (as stated in early Climate Change documents IPCC 1990, 1996):

(a) Design and implement national and international fishery-management institutions that recognize shifting species ranges, accessibility, and abundances and that balance species conservation with local needs for economic efficiency and stability.
(b) Support innovation by research on management systems and aquatic ecosystems.
(c) Expand aquaculture to increase and stabilize seafood supplies, help stabilize employment, and carefully augment wild stocks.
(d) In coastal areas, integrate the management of fisheries with other uses of coastal zones.
(e) Monitor health problems (e.g. red tides, ciguatera, cholera) that could increase under climate change and harm fish stocks and consumers.

The subjects that do not show up in the IPCC Reports are those that might resolve the more critical habitat and waterway access problems, or the rapidly degrading water quality as urbanization and agriculture expand. Today's most obvious series of environmental issues needing attention are those about controlling human growth and development, while monitoring, assessing and maintaining critical habitat – and retrofitting much of the that has been lost or manipulated.

This is primarily important because more options are necessary under known patterns of climate changes. Grand plans, for example, regarding increasing our dependence upon aquaculture, do little good if access to both clean, unpolluted water resources and adequate protein to feed to cultured species cannot be assured.

5. CONCLUSIONS

Regime shifts occur on several time and space scales. Identifying the precursors, or other indicators, can provide forecast capability that is key to better management of anthropogenic impacts on natural ecosystems. The negative Length of Day or Earth's Rotation Rate appears to offer useful insights into future ecosystem transitions, and potentially for more defined changes, once serious monitoring, and applied research is initiated. Monitoring the Atmospheric Indices and the consequent changes in “condition indicators”, distributions, and abundances of particularly responsive species provides the information necessary to initiate effective management of human activities that affect “ecosystems” and the production that is needed from them to sustain ourselves over the long term.

The sun is the primary source of energy in our solar system. The sun’s broad spectral radiance provides for life on our small piece of the universe. Nowhere is it so obvious that life is totally dependent upon the sun’s light, as in the world’s oceans where life evolved, and continues to respond to the continuous challenges of a rapidly changing environment. The issues involved are many, and complicated to interpret due to their interlocking dynamics – and to deal with as many of these influences remain obscure – but are not really outside our general human experience.

The seasonal oscillations of Earth’s sunlight levels are exaggerated at the poles, while remaining nearly constant about the equator. Lower seasonal variability and the relatively vast amount of light and heat absorbing ocean around the equator leads to the general warming at the equator. The critical fact that needs to be accepted before our messages can be converged and understood is that there is a continuous heat loss at the poles, and similarly, nearly continuous heat absorption into the equatorial oceans. Whatever processes modulate the polar heat losses, controls the Earth’s Climate Change patterns.

There are several distinct patterns of interest to those who track precipitation and drought in particular, and both coastal and ocean fisheries, in general. Many are related in somewhat obscure ways to the readily monitored changes in -LOD, as well as indices of the dominant wind-field, SST and Sea Level Pressure patterns over large Climate Zone Regions. Some of these have been identified as useful indicators of Climate Regime Shifts, as well as precursors of fisheries ecosystem responses, on decadal scales. Many are simply correlated, not forecastive. -LOD seems to offer the bast forecast indicator, to date, although it is certain that the changing -LOD per se, is Not the direct cause. It is an integrated signal that provides insight into future generic changes in ocean production, due to various forces, and allow the careful study of the links to ecological responses. Relevant forces include cloudiness and resultant light levels, wind speed and direction, coastal habitat temperatures, upwelling event frequencies, and freshwater runoff, all of which stimulate ecological cascades on all time scales.

While it is recognized that the energy at the equator “powers” the Earth’s Climate System, it is more convincing that much of the Earth’s Climate Forcing is initiated by Polar Cold Events (heat loss likely associated with low cloud densities), and resulting subsidence – that spawn Mobile Polar Highs. These, in turn, sweep equatorward, to gather surface energy and eventually energize the Trade Winds. If these MPHs are frequent and intense enough (and they encounter sufficiently energy-laden surface conditions), their role is enhanced and they continue their equatorward transfers. This leads to their further encounters with moisture laden frontal clouds likely resulting from Equatorial Deep Convection, causing state changes and precipitation, that enhances the transport of equatorial heat and energy poleward. Regimes shifts can be measured in terms of MPH frequencies and intensities, (c.f. Leroux 1998). Of course, Equatorial Heating and Warm Pool Dynamics are also important part of the processes involved, creating periods with more Equatorial Deep Convection (low SOI), and periods of lesser EDC (high SOI). All of these processes have local, regional and basin-scale ecological consequences.

The periodicity of various indices (PDO, NOA, and AO, ENSO, etc.) represent bipolar Ocean Climate Regimes (dominated by either East-West or Pole-Equator winds) and subsequent temperate to polar ocean physical and production responses, are being related to fisheries production patterns. Climate forcing is “noisy” within these various decadal and longer patterns, but never the less, provide useful insights into where, and what to monitor, that will help track the likely ecological responses. Transition periods are quite identifiable, if not particularly well studied, in ecological terms, simply because there are usually crises associated with the transition periods, as local expectations are not met due to shared debilities of the species arrays involved. Faunal changes observed by fishing communities are probably one of the most useful of all Climate Indicators.

It appears that over millennia, at least two quite distinct and dynamic faunas have evolved in each such marine ecosystem, only one half of which benefits from either side of the divergent contexts that result from the climate-driven physical processes. Several correlated physical dynamics can be identified, such as changes in precipitation patterns, related storage periods and water flow rates from rivers and streams, as well as local coastal ocean processes. It is also suggested that many migratory predator species are closely tuned to these changes, and can act as indicators of physical changes often only identified after the fact by oceanographers and climate researchers. There is not terrible concern about climate change and its consequences regarding most mobile ocean species as, historically, they have had considerable experience and have been selected for rapid response, and adaptability. Those regions with the strongest seasonal dynamics are home to species that are more adapted to change, and dynamic in both distribution and abundances, hence the amazing productivity of high latitude transition zones. Figure 25 provides insights into the regions of greatest seasonal dynamics.

While, little has been mentioned of the several hundred other species that are found and exploited to varying degrees in each marine ecosystem, there are several reasons to be just as concerned about their management. Once the focus on the major production fisheries shifts, there are always tendencies to adjust by maintaining production rates from lesser populous species. There is good reason to minimize the implicit refocus from production fisheries, until these secondary species have had time to adjust to the new conditions within their ecosystems. Perhaps, as in the case of Newfoundland's coastal fisheries during the period following the collapse of the cod fishery, an array of highly valued species might responded to decrease in predation, leading to more successful year class survival, hence very lucrative fishing for those fishermen equipped to fish them. On the other hand, the shift from one species set to another in tropical situations can lead to disasters, such as suffered by the giant clam, Tridacna, in the western Central Pacific Ocean due to intense removals.

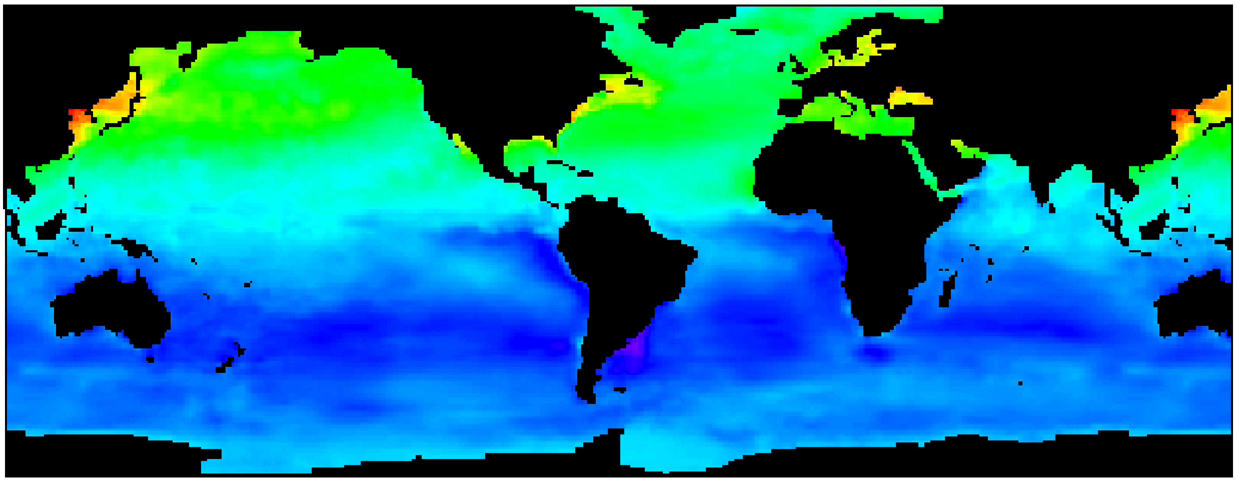

Figure 25 Shows the regions that have the greatest seasonal changes, and most adaptable species, and unusually productive ecosystems. Climatological 30-metre temperatures for the Northern Hemisphere Summer (August mean) have had the February mean values subtracted for each one degree square. The resulting difference were colour-scaled, and show that in the northern hemisphere the red to orange regions (i.e. the northwestern Atlantic and Pacific and the Mediterranean have large seasonal differences). In the southern hemisphere, it is the deep purple to maroon colour (e.g. off Argentina, Gulf of Guinea) that indicates strong seasonal differences. Coping with all such ecosystem dynamics "define" local survivors – another lesson to be learnt from the fishes.

At the same time, there is concern that the predominant effect on ocean and aquatic ecosystems, in general, is increasingly challenging the Earth's carrying capacity – not only for humans, but many other species – as havoc is caused for all species amongst all ecosystems by erasing habitats and removing options. It can assumed that despite human activities, the solar system will continue to reflect the long harmonic interactions that have evolved over millennia, long before life evolved, and will continue long after the present amicable conditions have shifted from today's supportive environments, toward ever more harsh ones – with inevitable consequences.

Perspectives on what is truly controllable needs to be revised, and recognize that ocean ecosystems begin on the highest mountains. Waterways and all downstream and coastal water quality are very much at the heart of the dilemma. High latitude dynamics and related ecological processes have been somewhat underemphasized, since most humans are averse to such extreme environments. If that should change, or our impacts in these regions become greater, it is clear that there will be dire consequences for those ecosystems, as well, as the species involved are truly specialized, and quite responsive to minor changes. They and all species need options even more than humans do, the most highly adaptable predators on Earth. In this respect, Earth's services to mankind are tightly linked to maintaining any and all options for the many species that comprise the many dynamic, interactive ecosystems that either cope with natural dynamics, or expire – the ultimate lesson from Nature.

REFERENCES

Abbes, R. & Bard F.-X. eds. 1999. ECOTAP, Etude du comportement des thonidés par l'acoustique et la pêche en Polynésie Française, Rapport Final. Convention Territoire, EVAAM-IFREMER – ORSTOM, Number 951070, 523 pp.

Alheit, J. & Hagen, E. 1997. Long-term climate forcing of European herring and sardine populations. *Fisheries Oceanography* 6(2): 130–139.

Allan, R., Lindesay, J. & Parker, D. 1996. El Niño Southern Oscillation & Climatic Variability, CSIRO Publication, 405 pp. plus CD-ROM.

Allen, B.D. & Anderson, R.Y. 1993, Evidence from western North America for rapid shifts in climate during the last glacial maximum. *Science*, 260: 1920–1923.

Anderson, R.Y. 1992. Possible connection between surface winds, solar activity, and the Earth's magnetic field, *Nature*, 358: 51–53.

Bakun, A. 1996. Patterns in the Ocean. California Sea Grant/CIB 323 pp.

Bakun, A. & Parrish, R.H. 1980. Environmental inputs to fishery population models for eastern boundary current. *In* G.D. Sharp, ed. Report and Documentation of the Workshop on the Effects of Environmental Variation on the Survival of Larval Pelagic Fishes, pp. 68–79. *IOC Workshop Rep. Ser*. No.28 Unesco, Paris.

Bakun, A., Beyer, J., Pauly, D., Pope, J.G. & Sharp, G.D. 1982. Ocean sciences in relation to living resources. *Can. J. Fish. Aquat. Sci.*, 39: 1059–1070.

Baranov, F.I. 1918. On the question of the biological basis of fisheries. *Nauchn. Issled. Ikhtiol. Inst. Izv*., 1: 81–128 (in Russian).

Baranov, F.I. 1926. On the question of the dynamics of the fishing industry. *Nauchn. Byull. Rybn. Khoz*., 8(1925): 7–11 (in Russian)

Barnett, T.P., Pierce, D.W. & Schnur, R. 2001. Detection of Anthropogenic Climate Change in the World's Oceans. *Science*, 292: 270–274.

Baumgartner, T.R., Soutar, A. & Ferreira-Bartrina, V. 1992. Reconstruction of the history of Pacific sardine and northern anchovy populations over the past two millennia from sediments of the Santa Barbara Basin, California. *CalCOFI Report,* 33: 24–40.

Baumgartner, T.R., Michaelsen, J., Thompson, L.G., Shen, G.T., Soutar, A. & Casey, R.E. 1989. The recording of interannual climatic change by high-resolution natural systems: tree-rings, coral bands, glacial ice layers, and marine varves. *In* Aspects of Climate Variability in the Pacific and Western Americas, pp. 1–15. *AGU Geophysical Monog*., 55.

Beamish, R.J. & Boulton, D.R. 1993. Pacific salmon production trends in relation to climate, *Canadian Journal of Fisheries and Aquatic Sciences,* 50: 1002–1016.

Bell, G.D., Halpert, M.R., Schnell, R., Higgins, J., Laevermore, V., Kousky, R., Tinker, W., Thiaw, M., Chelliah, M. & Artusa, A. 2000, Climate Assessment for 1999. *Bull. Am. Meteo. Soc,* 81: 1328–1370.

Belvèze, H. & Erzini, K. 1983. The influence of hydroclimatic factors on the availability of the sardine (*Sardinops pilchardus* Walbaum) in the Moroccan fishery. *In* G.D. Sharp & J. Csirke, eds. Proceedings of the Expert Consultation to Examine Changes in Abundance and Species Composition of Neritic Fish Resources, pp. 285–327. San Jose, Costa Rica, April 1983. *FAO Fisheries Report* No. 291(2).

Bertrand, A. & Josse, E. 1999. Acoustic characterisation of micronekton distribution in French Polynesia. *Prog. Mar. Ecol. Ser.*, 191: 127–140.

Boehlert, G.W. & Schumacher, J.D. 1997. Changing Oceans and Changing Fisheries: Environmental Data for Fisheries Research and Management. *NOAA Tech. Memo*. NOAA-TM-NMFS-SWFSC-239. 146 pp.

Braudel, F. 1985. Vol.1. The Structures of Everyday Life: the limits of the possible; Vol. 2. The Wheels of Commerce; Vol. 3. The Perspective of the World. Perennial Library – Harper and Row, New York.

Broecker, W.S. 1991. The great ocean conveyor. *Oceanography,* 4: 79–89.

Broecker, W.S. 1997. Thermohaline circulation, the Achilles heel of our climate system: Will man-made CO2 upset the current balance? *Science,* 278: 1592–1588.

Caddy, J.F. & Bakun, A. 1994. A tentative classification of coastal marine ecosystems based on dominant processes of nutrient supply. *Ocean and Coastal Management*, 23: 201–211.

Caddy, J.F. & Sharp, G.D. 1986. An ecological framework for marine fishery investigations. *FAO Fisheries Technical Paper* No. 283: 152 pp.

Crawford, R.J.M., Underhill, L.G., Shannon, L.V., Lluch-Belda, D., Siegfried, W.R. & Villacastin-Herero, C.A. 1991. An empirical investigation of trans-oceanic linkages between areas of high abundance of sardine. *In* T. Kawasaki, S. Tanaka, Y. Toba & A. Taniguchi. eds. *Long-Term Variability of pelagic Fish Populations and Their Environment*, pp. 319–332. Pergamon Press, Tokyo.

Csirke, J. 1980. Recruitment in the Peruvian anchovy and its dependence on the adult population. *Rapp. P.-v. Réun. CIEM.* 177: 307–313.

Csirke, J. & Sharp, G.D. eds. 1983. Report of the expert consultation to examine changes in abundance and species composition of neritic fish resources, San José, Costa Rica, 18–29 April 1983. *FAO Fisheries Report* No. 291 Vol. 1: 102 pp.

Cury, P., & Roy, C. 1989: Optimal environmental window and pelagic fish recruitment success in upwelling areas. *J. Can. Fish. Aquat. Sci.*, 46(4): 670–680.

Cushing, D.H. 1982. Climate and Fisheries. London, Academic Press, 373 pp.

Cushing, D.H. & Dickson, R.R. 1976. The biological response in the sea to climatic changes. *In* F.S. Russell & M. Yonge, eds. Advances in Marine Biology 14, pp. 1–122. Academic Press, London.

Dean, W.E., Bradbury, J.P. Anderson, R.Y. & Barnosky, K.W. 1984. The variability of Holocene climate change: evidence from varved lake sediments. *Science,* U.S. 226: 1191–1194.

Dobbs, D. 2000. *The Great Gulf.* Island Press, Shearwater Books, Washington DC. 206 pp.

Ebbesmeyer, C.C., Cayan, D.R. McClain, D.R. Nichols, F.H. Peterson, D.H. & Redmond, K.T. 1991. 1976 step in Pacific climate: Forty environmental changes between 1968–1975 and 1977–1984, *In* J.L. Betancourt & V.L. Tharp, eds. *Proceedings of the 7th Annual Pacific Climate (PACLIM) Workshop, April 1990,* pp. 115–126. California Department of Water Resources. Interagency Ecological Study Program Technical Report 26.

Enzel, Y., Cayan, D.R., Anderson, R.Y. & Wells, S.G. 1989. Atmospheric circulation during Holocene lake stands in the Mojave Desert: evidence of regional climatic change. *Nature*, 341: 44–47.

Fagan, B. 1999. Floods, Famines and Emperors:El Niño and the fate of civilizations. Basic Books, New York. 300 pp.

Finlayson, A.C. 1994. *Fishing for Truth* (Institute of Social and Economic Research) Memorial University, St. John's, Newfoundland.

Fonteneau, A. 1997. *Atlas of Tropical Tuna Fisheries: World Catches and the Environment*. L'Institut Français de Recherche Scientifique pour le Développement en Coopération, Paris.

Francis, R.C. & Hare, S.R. 1994. Decadal-scale regime shifts in the large marine ecosystems of the Northeast Pacific: a case for historical science. *Fish. Oceanogr.,* 3: 279–291.

Fréon, P. 1984. La variabilité des tailles individuelles a l'intérieur des cohortes et des bancs de poissons. 1. Observations et interprétation. *Oceanol. Acta,* 7(4): 457–468.

Friis-Christensen, E. & Lassen, K. 1991. Length of the solar cycle: An indicator of solar activity closely associated with climate. *Science*, 254: 698–700.

Garcia, S. 1988. Tropical penaeid prawns. *In* J.A. Gulland, ed. *Fish population dynamics: the implications for management*, pp. 219–249. Chichester, John Wiley and Sons Ltd., 422 pp.

Gauldie, R.W., Coote, G., Mulligan, K.P., West, I.F. & Merrett, N. 1991. Otoliths of deep water fishes: Structure, chemistry and chemically coded life histories. Comparative Biochemistry and Physiology, 100: 1–32.

Gauldie, R.W. & Sharp, G.D. 2001. Growth rate and recruitment: evidence from year-class strength in the year-to-year variation in the distribution of otolith weight, and fish length of *Hoplostethus atlanticus*. Vie et Milieu, 51(4): 267–287.

Giorgi, F. & Francisco, R. 2000. Evaluating uncertainties in the prediction of regional climate. *Geophysical Research Letters*, 27: 1295–1298.

Girs, A.A. 1971. *Macrocirculation method for long-term meteorological prognosis*. Hydrometizdat Publ., Leningrad, 480 pp. (in Russian).

Glantz, M.H. ed. 1992. *Climate Variability, Climate Change and Fisheries*. Cambridge University Press. 450 pp.

Glantz, M.H. & Feingold, L.E. eds. 1990. *Climate Variability, Climate Change and Fisheries.* Environmental and Societal Impacts Group, NCAR, Boulder, CO. 139 pp.

Glavin, T. 2000. *The Last Great Sea*. Greystone Books, Douglas & McIntyre Publishing Group, Vancouver. 244 pp.

Gomes, M.C., Haedrich, R.L. & Villagarcia, M.G. 1995. Spatial and Temporal Changes in the Groundfish Assemblages On the Northeast Newfoundland Labrador Shelf, Northwest Atlantic, 1978–1991. *Fisheries Oceanography*, 4(2): 85–101.

Gray, W.M. 1990: Strong association between west African rainfall and U.S. landfall of intense hurricanes. *Science*, 249: 1251–1256.

Gray, W.M. & Scheaffer, J.D. 1991. El Niño and QBO influences on tropical cyclone activity. *In* M.H. Glantz, R. Katz & N. Nicholls, eds. *ENSO Teleconnections linking worldwide climate anomalies: Scientific basis and societal impacts,* pp. 257–284. Cambridge university Press, Cambridge, UK.

Gross, R.S., Marcus, S.L., Eubanks, T.M., Dickey, J.O. & Keppenne, C.L. 1996. Detection of an ENSO signal in seasonal length-of-day variations, *Geophysical Research Letters*, 23: 3373–3376.

Gulland, J.A. 1983. Fish Stock Assessment. Wiley, London. 223 pp.

Halpert, M. & Bell, G. 1997. Climate Assessment for 1996. *Bull. Am. Meteo. Soc*., 8: 1–98.

Hare, S.R. & Francis, R.C. 1995. Climate change and salmon production in the Northeast Pacific Ocean. Spec. *In* R.J. Beamish, ed. Climate change and northern fish populations. *Pub. Can. Fish. Aquat. Sci*. 121: 357–372.

Harrison, P.J. & Parsons, T.R. eds. 2000. Fisheries Occeanography: An integrative approach to fisheries ecology and management. Fish and Aquatic Resources Series 4. Blackwell, *Science*, UK. 347 pp.

Hela, I. & Laevastu, T. 1971. Fish. Oceanogr. Blackwell, Fishing News, London.

Hilborn, R. & Walters, C.J. 1992. *Quantitative fisheries stock assessment. Choice, dynamics and uncertainty.* Chapman and Hall, Inc., London, New York: 570 pp. (with programs on diskette)

Hjort, J. 1914. The fluctuations in the great fisheries of northern Europe viewed in the light of biological research. *Rapp. P-v. Réun. Cons. Int. Explor. Mer.,* 20: 1–228.

Hjort, J. 1926. Fluctuations in the year classes of important food fishes*. J. Cons. Int. Explor., Mer.* 1: 5–38.

Hollowed, A.B. & Wooster, W.S. 1992. Variability of winter ocean conditions and strong year classes of Northeast Pacific groundfish. *ICES Marine Science Symposia* 195: 433–444.

Hollowed, A.B. & Wooster, W.S. 1995. Decadal-scale variations in the eastern subarctic Pacific: II. Response of Northeast Pacific fish stocks. *In* R.J. Beamish, ed. Climate change and northern fish populations. *Can. Spec. Pub. Fish. Aquat. Sci.*, 121: 373–385.

Hollowed, A.B., Bailey, K.M. & Wooster, W.S. 1995. Patterns of Recruitment in the northeast Pacific Ocean. *Biol. Oceanog.*, 5: 99–131.

Hoyt, D.V. & Schatten, K.H. 1997. *The Role of the Sun in Climate Change*, Oxford University Press, 279 pp.

Hubbs, C.L. 1960. Quaternary paleoclimatology of the Pacific coast of North America. *CalCOFI Rep.* VII: 105–112.

Hunter, J. & Sharp, G.D. 1983. Physics and fish populations: Shelf sea fronts and fisheries. *In* G.D. Sharp & J. Csirke, eds. Proceedings of the Expert Consultation to Examine the Changes in Abundance and Species Composition of Neritic Fish Resources, pp. 659–682. San Jose, Costa Rica, 18–29 April 1983. *FAO Fisheries Report* No. 291, vol. 2. FAO, Rome.

Idso, S. 1982. Carbon Dioxide: Friend of Foe? 72 pp.

Iles, T.C. & Sinclair, M. 1982. Atlantic Herring. Stock discreteness and abundance. *Science*.215: 627–633.

IPCC. 1990. Impacts Assessment of Climate Change. The policymaker's summary of the Report of Working Group II to the Intergovernmental Panel on Climate Change. WMO/UNEP. Australian Government Publishing Service. Canberra.

IPCC. 1996. Climate Change 1995 – The Science of Climate Change – Working Group I report, 1996, 584 pp., Climate Change 1995 – Impacts, Adaptations and Mitigation of Climate Change – Working Group II report, 1996, 880 Climate Change 1995 – Economic and Social Dimensions of Climate Change – Working Group III report, 1996, 608 pp. Cambridge Univ. Press, New York.

IPCC. 2001. Climate Change 2001: Synthesis Report. contribution of Working Groups I, II and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change. R.T. Watson & Core Writing Team, eds. Contains Synthesis Report, Summaries for Policymakers and Technical Summaries of the three Working Group volumes, and supporting Annexes. Cambridge University Press, UK. 398 pp.

Kawai, T. & Isibasi, K. 1983. Change in abundance and species composition of neritic pelagic fish stocks in connection with larval mortality caused by cannibalism and predatory loss by carnivorous plankton. *In* Proceedings of the Expert Consultation to Examine Changes in Abundance and Species Composition of Neritic Fish Resources, pp. 1081–1111. *FAO Fisheries Report* No. 291(3).

Kawasaki, T. 1983. Why do some fishes have wide fluctuations in their number? – A biological basis of fluctuation from the viewpoint of evolutionary ecology. *In* G.D. Sharp & J. Csirke, eds. Proceedings of the Expert Consultation to Examine Changes in Abundance and Species Composition of Neritic Fish Resources, pp. 1065–1080. *FAO Fisheries Report* No. 291(3).

Kawasaki, T., Tanaka, S. Toba, Y. & Taniguchi, A. eds. 1991. *Long-term Variability of Pelagic Fish Populations and Their Environment.* Pergamon Press, Tokyo.

Kendall, A.W. Jr., Perry, R.I. & Kim, S. 1996. Fisheries oceanography of the walleye pollock in Shelikof Strait, Alaska. *Fish. Oceanogr.,* 5(Suppl.1): 203 pp.

Klyashtorin, L.B. 1998. Long-term climate change and main commercial fish production in the Atlantic and Pacific. *Fisheries Research* 37: 115–125.

Klyashtorin, L.B. 2001. Climate change and long term fluctuations of commercial catches: the possibility of forecasting. Rome, *FAO Fisheries Technical Paper* No. 410: 98 pp.

Klyashtorin, L.B., Nikolaev A., & Klige, R. 1998. Variation of global climate indices and Earth rotation velocity. *In* Book of Abstracts GLOBEC First Open Science Meeting, Paris, 17–20 March 1998. 55 pp.

Klyashtorin, L.B., Nikolaev, A.V. & Lubushin, A.A. (. Fluctuations of Global Climatic Indices and the Earth Rotation Velocity. *Geoecology, Engineering Geology, Hydrogeology, Geocryology*, Proceedings of Russian Academy of Sciences series, Moscow.

Kondo. K. 1980. The recovery of the Japanese sardine – the biology basis of stock size fluctuations. *Rapp. P-v. Réun. Cons. Int. Explor. Mer.,* 177: 332–352.

Koslow, J.A. 1992. Fecundity and the Stock-Recruitment relationship *Can. J. Fish. Aquat. Sci.,* 49: 210–217.

Koslow, J.A., Thompson, K.R. & Silvert, W. 1987. Recruitment to northwest Atlantic cod, *Gadus morhua* and haddock, *Melanogrammus aeglefinus* stocks: influence of stock size and climate, *Canadian Journal of Fisheries and Aquatic Sciences,* 44: 26–39.

Laevastu, T. & Favorite, F. 1980. Holistic simulation models of shelf-sea ecosystems. *In* A.R. Longhurst, ed. *Analysis of Marine Ecosystems,* pp. 701–727. Academic Press, London.

Lasker, R. 1978. The relation between oceanographic conditions and larval anchovy food in the California current: factors leading to recruitment failure. *Rapp. P-v. Réun. Cons. Int. Explor. Mer.,* 173: 212–230.

Le Blanc, J-L. & Marsac, F. 1999. Climate Information and Prediction Services for Fisheries: the case of tuna fisheries, CLIMAR 99 – WMO Workshop on Advances in Marine Climatology, Vancouver (CA) 8–15 September 1999, pp. 30.

Lean, J. & Rind, D. 1998. Climate forcing by changing solar radiation, *Journal of Climate*, 11(12): 3069–3091.

Leggett, W.C., Frank, K.T. & Carscadden, J.E. 1984. Meteorological and hydrographic regulation of year-class strength in capelin (*Mallotus villosus*). *Canadian Journal of Fisheries and Aquatic Sciences,* 41: 1193–1201.

Leroux, M. 1998. *Dynamic Analysis of Weather and Climate*, Wiley/Praxis series in Atmospheric Physics, John Wiley & Sons, Publishers. 365 pp.

Levitus, S., Antonov, J.I., Boyer, T.P. & Stephens, C. 2000. Warming of the world ocean. *Science*, 287: 2225–2229.

Loeb, V.E., Smith, P.E. & Moser, H.G. 1983a. Ichthyoplankton and zooplankton abundance patterns in the California Current area, 1975. *CalCOFI Rep.,* 24: 109–131.

Loeb, V.E., Smith, P.E. & Moser, H.G. 1983b. Geographical and seasonal patterns of larval fish species structure in the California Current area, 1975. *CalCOFI Rep.,* 24: 132–151.

Loeb, V., Siegel, V., Holm-Hansen, O., Hewitt, R., Fraser, W., Trivelpiece, W. & Trivelpiece, S. 1997. Effects of sea-ice extent and krill or salp dominance on the Antarctic food web. *Nature,* 387: 897–900.

Longhurst, A.R. 1995. Seasonal cycles of pelagic production and consumption. *Prog. Oceanog*., 36: 77–167.

Longhurst, A.R., Sathyendranath, S., Platt, T. & Cayerhill, C.M. 1995. An estimate of global primary production in the ocean from satellite radiometer data, *J. Plankton Res.*, 17(6): 1245–1271.

McFarlane G.A., King, J.R. & Beamish, R.J. 2000. Have there been recent changes in climate? Ask the fish, *Progress in Oceanography*, 47: 147–169.

McGowan, J.A., Cayan, D.R & Dorman, L.M. 1998. Climate-ocean variability and ecosystem response in the northeast Pacific. *Science,* 281: 210–217.

Mantua, N.J., Hare, S.R., Zhang, Y., Wallace, J.M. & Francis, R.C. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. *Bull. Amer. Meteor. Soc.,* 78: 1069–1079.

Markgraf, V. ed. 2001. *Interhemispheric Climate Linkages*, Academic Press, San Diego, CA.

Marsac, F. & Hallier, J.P. 1991. The recent drop in the yellowfin catches by the western Indian Ocean purse fishery: overfishing or oceanographic changes. *In* Proceedings of the Expert Consultation on the Stock Assessment of Tunas in the Indian Ocean. Bangkok, Thailand, 2–6 July 1990. Colombo Sri Lanka, Indian Ocean Commission.

Martin, J.H., Gordon, R.M. & Fitzwater, S.E. 1991. Iron limitation? The case for iron. *Limnol. Oceanogr.* 36(8): 1793–1802.

Moser, H.G., Smith, P.E. & Eber, L.E. 1987. Larval fish assemblages in the California Current, 1951–1960, a period of dynamic environmental change. *CalCOFI Rep.* XXVIII.

Murawski, S.A. 1993. Climate change and marine fish distributions: forecasting from historical analogy. *Transactions of the American Fisheries Society,* 122: 647–658.

Nixon, S.W. 1982. Nutrient dynamics, primary production and fisheries yields of lagoons. *Oceanol. Acta,* 4(suppl): 357–371.

Nixon. S.W. 1988. Physical energy inputs and the comparative ecology of lake and marine ecosystems. *Limnol. Oceanogr.,* 33(4, part2): 1005–1025.

Nixon, S.W. 1989. Microscale and finescale variations of small plankton in coastal and pelagic environments. *J. Mar. Res.,* 47: 197–240.

Nixon, S.W. 1997. Prehistoric nutrient inputs and productivity in Narragansett Bay. *Estuaries,* 20(2): 253–261.

Norton, J.G. & Mason, J.E. Environmental influences on species composition of the commercial harvest of finfish and invertebrates off California. *CalCOFI Report Series.* Accepted for publication June 2003. (In press).

Parrish, R.H. & MacCall, A.D. 1978. Climatic variation and exploitation in the Pacific mackerel fishery. *Calif. Dep. Fish. Game Fish. Bull.,* 167: 109 pp.

Pauly, D. & Matsubroto, P. 1996. Baseline Studies of Biodiversity: the Fisheries Resources of Western Indonesia. *ICLARM Stud. Rev.* 21, 321 pp.

Pauly, D. & Tsukayama, I. eds. 1987. *The Peruvian Anchoveta and its Upwelling Ecosystem*: *Three Decades of Change*. IMARPE; GTZ; ICLARM, Callao, Peru. 351 pp.

Pauly, D., Muck, P., Mendo, J. & Tsukayama, I. eds. 1989. *The Peruvian Anchoveta and its Upwelling Ecosystem*: *Dynamics and Interactions*. IMARPE;GTZ;ICLARM, Callao, Peru. 438 pp.

Pauly, D., Christensen, J., Dalsgaard, J., Froese, R. & Torres, F. Jr. 1998. Fishing down marine food webs. *Science,* 279: 860–863.

Pearcy, W.G. 1966. Salmon production in changing ocean domains. *In* D.J. Stouder, P.A. Bisson & R.J. Naiman, eds. *Pacific Salmon and their Ecosystems*: *Status and Future Options,* pp. 331–352. Chapman and Hall, New York.

Perry, C.A. 1994. Solar-irradiance variations and regional precipitation fluctuations in the western United States: *International Journal of Climatology*, 14: 969–983.

Perry, C.A. 1995. Association between solar-irradiance variations and hydroclimatology of selected regions of the USA. *In* Proceedings of 6th International Meeting on Statistical Climatology, Galway, Ireland, June 19–23, 1995, pp. 239–242. Steering Committee for International Meetings on Statistical Climatology.

Perry, C.A. 2000. A regression model for annual streamflow in the upper Mississippi River Basin based on solar irradiance. *In* G.J. West & L. Buffaloe, eds., Proceedings of the Sixteenth Annual Pacific Climate Workshop, Santa Catalina Island, California, May 24–27, 1999; *Interagency Ecological Program for Sacramento-San Joaquin Delta Technical Report*. 65: 161–170.

Perry, C.A. & Hsu, K.J. 2000. Geophysical, archaeological, and historical evidence support a solar-output model for climate change: Proceedings of National Academy of Science, 97(23): 1244–1248.

Polovina, J.J. 1984a. An overview of the ECOPATH model. *ICLARM Fishbyte,* 2(2): 5–7

Polovina, J.J. 1984b. Model of the coral reef ecosystem. Part I. The ECOPATH model and its application to French frigate shoals. *Coral Reefs*, 3(1): 1–11.

Polovina, J.J., Mitchum, G.T. & Evans, O.T. 1995. Decadal and basin-scale variation in mixed layer depth and the impact on biological production in the Central and North Pacific. 1960–88. *Deep Sea Res*., 42: 1710–1716.

Quinn, W.H. 1992. A study of Southern Oscillation-related climatic activity for A.D. 622–1900 incorporating Nile River flood data. *In* H.F. Diaz & V. Markgraf, eds. *El Niño*: *historical and paleoclimatic aspects of the Southern Oscillation,* pp. 119–149. Cambridge University Press.

Reid, P.C., Planque, B. & Edwards, M. 1998. Is observed variability in the long-term results of the Continuous Plankton Recorder survey a response to climate change? *Fisheries Oceanography,* 7: 282–288.

Reid, P.C., Edwards, M., Hunt, H.G. & Warner, A.J. 1998. Phytoplankton change in the North Atlantic, *Nature,* 391: 546.

Russell, F.S. 1931. Some theoretical considerations on the "overfishing" problem. *J. Cons. CIEM*, 6: 1–20.

Russell, F.S. 1973. A summary of the observations of the occurrence of planktonic stages of fish off Plymouth 1924–1972. *J. Mar. Biol. Assn. NS UK*, 53: 347–355.

Scheiber, H.N. 1990. California marine research and the founding of modern fisheries oceanography: CALCOFI's early years, 1947–1964. *CalCOFI Rep*., 31: 63–83.

Schulein, F.H., Boyd, A.J. & Underhill, L.G. 1995. Oil to meal ratios of pelagic fish taken form the northern and southern Benguela system: seasonal patterns and temporal trends, 1951–1993. *S. Afr. J. Mar. Sci.,* 15: 61–82.

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.E., 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. *S. Afr. J. Mar. Sci.,* 21: 289–347.

Sharp, G.D. 1976. Vulnerability of tunas as a function of environmental profiles. *In* Maguro Gyokyo Kyogikay Gijiroku, Suisano-Enyo Suisan Kenkyusho. Proceedings of the Tuna Fishery Research Conference, Fisheries Agency – Far Seas Fisheries Research Laboratory, Shimizu, Japan. (In English and Japanese).

Sharp, G.D. 1978. Behavioural and physiological properties of tunas and their effects on vulnerability to fishing gear. *In* G.D. Sharp & A.E. Dizon, eds. *The Physiological Ecology of Tunas,* pp. 397–449. Academic Press. San Francisco and New York.

Sharp, G.D. 1981a. Report of the Workshop on Effects of Environmental Variation on the Survival of Larval Pelagic Fishes. *In* G.D. Sharp, ed. Report and Documentation of the Workshop on the Effects of Environmental Variation on the Survival of Larval Pelagic Fishes, pp. 6–62. *IOC Workshop Rep. Ser*. No.28 Unesco, Paris.

Sharp, G.D. 1981b. Colonization: modes of opportunism in the ocean. *In* G.D. Sharp, ed. Report and Documentation of the Workshop on the Effects of Environmental Variation on the Survival of Larval Pelagic Fishes, pp. 125–148. *IOC Workshop Rep. Ser.* No. 28 Unesco, Paris.

Sharp, G.D. 1987. Climate and Fisheries: cause and effect or managing the long and short of it all. *In* A.I.L. Payne, J.A. Gulland & K.H. Brink, eds. The Benguela and Comparable Ecosystems. *S. Afr. J. Mar. Sci*., 5: 811–838.

Sharp, G.D. 1988. Fish Populations and Fisheries: their perturbations, natural and man induced. *In* H. Postma & J.J. Zijlstra, eds. *Ecosystems of the World 27, Continental Shelves,* pp. 155–202. Elsevier, Amsterdam.

Sharp, G.D. 1991. Climate and Fisheries: Cause and Effect – A system review. *In* T. Kawasaki, S. Tanaka, Y. Toba & A. Taniguchi, eds. *Long-term Variability of Pelagic Fish Populations and Their Environment,* pp. 239–258. Pergamon Press, Tokyo.

Sharp, G.D. 1992a. Climate Change, the Indian Ocean Tuna Fishery, and Empiricism. *In* M.H. Glantz, ed. Climate Variability, Climate Change and Fisheries, pp. 377–416. Cambridge University Press.

Sharp, G.D. 1992b. Fishery Catch Records, ENSO, and Longer Term Climate Change as Inferred from Fish Remains From Marine Sediments. *In* H. Diaz & V. Markgraf, eds. *Paleoclimatology of El Niño – Southern Oscillation*, pp. 379–417. Cambridge University Press.

Sharp, G.D. 1995. Its about time: new beginnings and old good ideas in fisheries science. *Fish. Oceanogr*., 4(4): 324–341.

Sharp, G.D. 1997. Its About Time: Rethinking fisheries management. *In* Hancock, Smith, Grant and Beumer, eds. *Developing and Sustaining World Fisheries Resources*: *The state of science and management,* pp. 731–736. CSIRO, Australia.

Sharp, G.D. 1998. The Case for Dome-Shaped response Curves by Fish Populations *In* M-H. Durand, P. Cury, R. Mendelssohn, C. Roy, A. Bakun & D. Pauly, ed. *Global versus Local Changes in Upwelling Systems*, pp. 503–524. A report from the CEOS Workshop, Monterey, California, September, 1994. ORSTOM Editions, Paris.

Sharp, G.D. 2000. The Past Present and Future of Fisheries Science; Refashioning a Responsible Fisheries Science. *In* P.J. Harrison & T.R. Parsons, eds. *Fisheries Oceanography*: *an integrative approach to fisheries ecology and management,* pp. 207–262. Blackwell Science, UK.

Sharp, G.D. 2001. A Brief Overview of the History of Fish Culture and its Relation to Fisheries Science. Proceedings of the Tenth Biennial Conference of the International Institute of Fisheries Economics and Trade, July, 2000, available on CD-ROM from IIFET Secretariat, OSU, Corvallis, Oregon.

Sharp, G.D. & Csirke, J. eds. 1983. Proceedings of the Expert Consultation to Examine the Changes in Abundance and Species Composition of Neritic Fish Resources, San Jose, Costa Rica, 18–29 April 1983. *FAO Fisheries Report,* No. 291, Vols 2–3. 1294 pp.

Sharp, G.D., Csirke, J. & Garcia, S. 1983. Modelling Fisheries: What was the Question? *In* G.D. Sharp & J. Csirke, eds. Proceedings of the Expert Consultation to Examine Changes in Abundance and Species Composition of Neritic Fish Resources. San Jose, Costa Rica, April 1983, pp. 1177–1224. *FAO Fisheries Report* No. 291(3).

Sharp, G.D., Klyashtorin, L. & Goodridge, J.G. 2001a. Forecasting Ocean Ecosystem Responses to Various Climate Clocks, 2001. *In* G.J. West & L.D. Buffaloe, eds. *Proceedings of the Seventeenth Annual Pacific Climate Workshop,* pp. 65–90. Technical Report 67 of the Interagency Ecological Program for the San Francisco Estuary.

Sharp, G.D., Klyashtorin, L. & Goodridge, J.G. 2001b. Climate and Fisheries: Costs and benefits of Change. *In Proceedings of the Tenth Biennial Conference of the International Institute of Fisheries Economics and Trade, July, 2000,* available on CD-ROM from IIFET Secretariat, OSU, Corvallis, Oregon.

Sharp, G.D., Klyashtorin, L. & Goodridge, J.G. 2002. The New Regimes: Fish Stories and Society, Extended abstract/joint poster on long-term consequences of Climate Forcing, PACLIM, Asilomar, April 2001. *In* G.J. West & L.D. Buffaloe, eds. Proceedings of the Eighteenth Annual Pacific Climate Workshop, Technical Report (in press) of the Interagency Ecological Program for the San Francisco Estuary.

Shen, G.T., Cole, J.E. Lea, D.W., Linn, L.J., McConnaughey, T.A. & Fairbanks, R.G. 1992. Surface ocean variability at Galápagos from 1936–1982: Calibration of geochemical tracers in corals. *Paleoceanography,* 7: 563–583.

Sinclair, M. 1988. *Marine populations*: *An essay on population regulation and speciation. Books in recruitment fishery oceanography*. Washington Sea Grant Program. University of Washington Press, Seattle and London. 252 pp.

Smith, P.E. 1978. The biological effects of ocean variability: time and space scales of biological response. *Rapp. P-v. Réun. Cons. Int. Explor. Mer.,* 173: 112–127.

Soutar, A. & Crill, P.A. 1977. Sedimentation and climatic patterns in the Santa Barbara Basin during the 19th and 20th centuries. *Bull. Geol. Soc. of America,* 88: 1161–1172.

Soutar, A. & Isaacs, J.D. 1974. Abundance of pelagic fish during the 19th and 20th centuries as recorded in anaerobic sediments of the Californias. *Fish. Bull., US,* 72: 257–273.

Southward, A.J. 1974a. Changes in the plankton community in the western English Channel. *Nature*, 259: 5433.

Southward, A.J. 1974b. Long term changes in abundance of eggs in the Cornish pilchard (*Sardina pilchardus*, Walbaum) off Plymouth. *J. Mar. Biol. Assn. UK NS,* 47: 81–95.

Southward, A.J., Boalch, G.T. & Mattock, L. 1988. Fluctuations in the herring and pilchard fisheries of Devon and Cornwall linked to change in climate since the 16th century. *J. Mar. Biol. Assoc. UK*, 68: 423–445.

Southward, A.J., Butler, E.I. & Pennycuick, L. 1975. Recent cyclic changes in climate and abundance of marine life. *Nature*, 253: 714–717.

Sonechkin, D.M. 1998. Climate dynamics as a nonlinear Brownian motion. *International Journal of Bifurcation and Chaos,* 8(4): 799–803

Sonechkin, D.M., Datsenko, N.M. & Ivaschenko, N.N. 1997.Estimation of the global warming trend by Wavelet Analysis. *Izvestia, Atmospheric and Oceanic Physics,* 33(2): 184–194.

Taylor, K. 1999. Rapid Climate Change. *American Scientist.* July–August 1999 issue.

Thompson, M-F. & Tirmizi, N.M. eds. 1995. *The Arabian Sea – living marine resources and the environment*. Vanguard books (PVT) LTDm Lahore, Pakistan. 732 pp.

Thompson, L.G., Mosely-Thompson, E., Davis, M.E., Lin, P.-N., Henderson, K.A., Cole-Dai, J., Bolzon, J.F. & Liu, K.-B. 1995. Late glacial stage and holocene tropical ice core records from Huascaran, Peru, *Science*, 269: 46–48.

Ursin, E. 1982. Stability and variability in the marine ecosystem. *Dana*, 2: 51–67.

Vangeneim, G.Ya. 1940. Long-term prediction of air temperature river debacle. *National Hydrological Institute*, 10: 207–236 (in Russian).

Ware, D.M. 1995. A century and a half of change in the climate of the NE Pacific. *Fish. Oceanogr*., 4(4): 267–277.

Ware, D.M. & McFarlane, G.A. 1989. Fisheries production domains in the Northeast Pacific Ocean. *In* R.J. Beamish & G.A. McFarlane eds. Effects of ocean variability on recruitment and an evaluation of parameters used in stock assessment models, pp. 359–379. *Canadian Special Publication of Can. Fish. Aquat. Sci.,* 108.

Ware, D.M. & Thompson, R.E. 1991. Link between long-term variability in upwelling and fish production in the northeast Pacific Ocean. *Can. J. Fish. Aquat. Sci*., 48(12): 2296–2306.

Welchmeyer, N.A and several others. 1999. EOS, 80: 248 pp.

White, W.B., Chen, S.-C. & Peterson, R. 1998. The Antarctic Circumpolar Wave: A beta-effect in ocean-atmosphere coupling over the Southern Ocean. *J. Physical Oceanography*, 28: 2345–2361.

White, W.B., Lean, J., Cayan, D.R. & Dettinger, M.D. 1997. A response of global upper ocean temperature to changing solar irradiance. *J. Geophysical Research*, 102: 3255–3266.

Wyatt, T. & Larrañeta, M.G. eds. 1988. Long Term Changes in Marine Fish populations. *Proceedings of a Symposium in Vigo, Spain 18–21 Nov. 1986*. Imprento REAL, Bayona.

Wyllie-Echevarria, T. & Wooster, W.S. 1998. Year-to-year variations in Bering Sea ice cover and some consequences for fish distributions, *Fish. Oceanogr*., 7: 159–170.

Zachos, J.C., Shackleton, N.J., Revenaugh, J.S., Heiko Palike & Flower, B.P. 2001. Climate Response to Orbital Forcing Across the Oligocene-Miocene Boundary. *Science,* 292: 274–274.

Zorita, E. & Gonzalez-Rouco, F. 2000. Disagreement between predictions of the future behaviour of the Arctic Oscillation as simulated in two different climate models: Implications for global warming. *Geophysical Research Letters*, 27: 1755–1758.

ANNEX I

RECOMMENDED FURTHER READING
(relevant papers and web pages not cited in the main document

Anderson, R.Y. 1992a. Long term changes in the frequency of occurrence of El Niño events. *In* H.D. Diaz & V. Markgraf, eds. *El Niño*: *historical and Paleoclimatic Aspects of the Southern Oscillation,* Cambridge University Press.

Anderson, R.Y. 1992b. Solar Variability Captured in Climatic and High-Resolution Paleoclimatic Records: A Geological Perspective. *In* C.P. Sonnet, M.S. Giampapa & M.S. Matthews, eds. The Sun in Time, University of Arizona Press.

Anderson, R.Y. & Allen, B.D. 1993. Evidence from western North America for rapid shifts in climate during the last glacial maximum, *Science*, 260: 1920–1923.

Bakun, A. & Parrish, R.H. 1990. Comparative studies of coastal pelagic fish reproductive habits: the Brazilian sardine (*Sardinella aurita). J. Cons. Int. Explor. Mer.*, 46: 269–283.

Bakun, A. & Parrish, R.H. 1991. Comparative studies of coastal pelagic fish reproductive habitats: the anchovy (*Engraulis anchoita*) of the southwestern Atlantic. *J. Cons. Int. Explor. Mer.*, 48: 342–361.

Beamish, R.J. 1993. Climate change and exceptional fish production off the west coast of North America, *Canadian Journal of Fisheries and Aquatic Sciences,* 50: 2270–2291.

Beamish, R.J. & McFarlane, G.A. eds. 1989. Effects of ocean variability on recruitment and an evaluation of parameters used in stock assessment models. *Canadian Special Publication of Can. Fish. Aquat. Sci.,* 108.

Beverton, R.J.H. & Holt, S.J. 1957. On the dynamics of exploited fish populations. *Fish. Invest. Minist. Agric. Fish. Food G.B. (2 Sea Fish.)*, 19: 533 pp.

Beyer, J. & Sparre, P. 1983. *Modelling exploited fish stocks. In* S.E. Jørgensen, ed. *Application of ecological modelling in environmental management. Part A*., pp. 485–582. Amsterdam, Elsevier Scientific Publishing Co.

Bigg, G.R., T. D. Jickells, P. S. Liss, T. J. Osborn, 2003. The Role of the Oceans in Climate. *International Journal of Climatology* 23(10):1127–1159, August 2003.

Broecker, W.S., Sutherland, S. & Peng, T.-H. 1999. A possible 20th-Century slowdown of Southern Ocean deep water formation. *Science,* 286(5442): 1132–1135.

Cole, J.E., Dunbar, R.B., McClanahan, T.R. & Muthiga, N.A. 2000. Tropical Pacific forcing of decadal SST variability in the western Indian Ocean over the past two centuries. *Science*, 287: 617–619.

Dore, J.E. R. Lukas, D.W. Sadler & D.M. Karl. 2003. Climate-driven changes to the atmospheric CO2 sink in the subtropical North Pacific Ocean. *Nature,* 424, 754–757 (14 August 2003)

Durand, M.-H., Cury, P., Mendelssohn, R., Roy, C., Bakun, A. & Pauly, D. eds. 1998. *Global versus Local Changes in Upwelling Systems – a report from the CEOS Workshop, Monterey, California, September, 1994*. ORSTOM Editions, Paris. 594 pp.

Fasham, M.J.R. ed. 1984. *The Flows of Energy and Materials in Marine Ecosystems, Theory and Practice*. Plenum Press, New York. 733 pp.

Garcia, S. & LeReste, L. 1981. Life cycles, dynamics, exploitation and management of coastal penaeid shrimp stocks. *FAO Fisheries Technical Paper* No. 203: 215 pp. (original in French, same ref.).

Glantz, M.H. 1996. Currents of Change: *El Niño's Impact on Climate and Society*. Cambridge University Press, 200 pp.

Glantz, M.H. & Thompson, J.D. eds. 1981. Resource Management and Environmental Uncertainty: Lessons from coastal upwelling fisheries. *P. Adv. Env. Sci.,* 11, Wiley-Interscience. 491 pp.

Glantz, M.H., Katz, R. & Krenz, M. 1987. *The Societal Impacts Associated with the 1982–83 Worldwide Climate Anomalies.* NCAR/ESIG, Boulder, Colourado. 105 pp.

Glantz, M.H., Katz, R. & Nicholls, N. eds. 1991. *ENSO Teleconnections linking worldwide climate anomalies*: *Scientific basis and societal impacts*. Cambridge university Press, Cambridge, UK.

Glynn, P.W. ed. 1990. Global Ecological Consequences of the 1982–83 El Niño-Southern Oscillation. Elsevier Oceanography Series, 52, Elsevier, Amsterdam. 563 pp.

Graham, M. 1935. Modem theory of exploiting a fishery and application to North Sea trawling. *J. Cons. CIEM*, 10(3): 264–274.

Helle, J.H. & Hoffman, M.S. 1995. Size decline and older age at maturity of two chum salmon (*Oncorhynchus keta*) stocks in western North America, 1972–92. III: *In* R.J. Beamish, ed. Climate and northern fish populations. *Can. Spec. Pub. Fish. Aquat. Sci*., 121: 245–260.

Hunter, J.R. & Sharp, G.D. 1983. Physics and fish populations: Shelf sea fronts and fisheries. *In* G.D. Sharp & J. Csirke, eds. Proceedings of the Expert Consultation to Examine the Changes in Abundance and Species Composition of Neritic Fish Resources, pp. 659–682. San Jose, Costa Rica, 18–29 April 1983. Rome. *FAO Fisheries Report* No. 291, Vol. 2.

Isaacs, J.D. 1976. Some ideas and frustrations about fishery science. *CalCOFI Rep.* XVIII: 34–43.

Larkin, P.A. 1977. An epitaph for the concept of maximum sustainable yield. *Trans. Am. Fish. Soc*., 106(1): 1–11.

Laevastu, T. 1993. *Marine Climate, Weather and Fisheries*. Wiley and Sons, Inc. Halstead press. 204 pp.

Lluch-Belda, D., Schwartzlose, R.A., Serra, R., Parrish, R., Kawasaki, T., Hedgecock, D. & Crawford, R.J.M. 1992. Sardine and anchovy regime fluctuations of abundance in four regions of the world oceans: a workshop report. *Fish. Oceanogr.*, 1(4): 339–347.

Lluch-Belda, R., Crawford, J.M., Kawasaki, T., MacCall, A.D., Parrish, R.H., Schwartzlose, R.A. & Smith, P.E. 1989. World-wide fluctuations of sardine and anchovy stocks: The regime problem. *S. Afr. J. Mar. Sci*., 8: 195–205.

Mallicoate, D.L. & Parrish, R.H. 1981. Seasonal growth of California stocks of northern anchovy, *Engraulis mordax*, Pacific mackerel, *Scomber Japonicus*, and jack mackerel, *Trachurus symmetricus*. *CalCOFI Rep.* Vol XXII: 69–81.

Murphy, G.I. 1982. Recruitment of tropical fishes. *In* D. Pauly & G.I. Murphy, eds. 1982. *Theory and management of tropical fisheries. Proceedings of the ICLARM/CSIRO workshop on the theory and management of tropical multispecies stocks*, 12–21 January 1981, pp. 141–148. Cronulla, Australia. *ICLARM Conf. Proc.*, 9: 360 pp.

Overpeck, J.T. 1996. Warm climate surprises. *Science,* 271: 1820–1821.

Owen, R.W. 1981 Patterning of flow and organisms in the larval anchovy environment. *In* G.D. Sharp, ed. Report and Documentation of the Workshop on the Effects of Environmental Variation on the Survival of Larval Pelagic Fishes, pp.167–200. *IOC Workshop Rep. Ser*. No. 28. UNESCO, Paris.

Parrish, R. & Mallicoate, D. 1995. Variation in the condition factors of California pelagic fishes and associated environmental factors. *Fish. Oceanogr*., 4(2): 171–190.

Parrish, R.H., Nelson, C.S. & Bakun, A. 1981. Transport mechanisms and reproductive success of fishes in the California Current. *Biol. Ocean*., 1(2): 175–203.

Parker, K.S., Royer, T.C. & Deriso, R.B. 1995. High-climate forcing and tidal mixing by the 18.6-year lunar nodal cycle and low-frequency recruiting trends in Pacific halibut (*Hippoglossus stenolepis*). *In* R.J. Beamish, ed. Climate Change and Northern Fish Populations, pp. 447–459. *Pub. Can. Fish. Aquat. Sci.,* 121.

Pauly, D. 1983. Some simple methods for the assessment of tropical fish stocks. *FAO Fisheries Technical Paper* No. 234: 52 pp. Issued also in French and Spanish.

Pearcy, W.G. ed. 1984: The Influence of Ocean Conditions on the Production of *Salmonids In the North Pacific*: *a workshop*. 8–10 November 1983, Newport, Oregon. Oregon State University Sea Grant College Program. 327 pp.

Pearcy, W.G. 1992. *Ocean ecology of North Pacific salmonids*. Univ. Washington Press, Seattle 179 pp.

Pearcy, W.G., Fisher, J., Brodeur, R. & Johnson, S. 1985. Effects of the 1983 El Niño on coastal nekton off Oregon and Washington. *In* W.S. Wooster & D.L. Fluharty, eds. *El Niño North*: *Niño effects on the eastern subarctic Pacific,* pp. 188–204. Washington Sea Grant Pub. WSG-WO-85–3.

Polovina, J.J. 1996. Decadal variation in the trans Pacific migration of northern bluefin tuna (*Thunnus thynnus*) coherent with climate-induced change in prey abundance, *Fisheries Oceanography,* 5: 114–119.

Quinn, W.H., Neal, V.T. & Antunez de Mayolo, S.E. 1987. El Niño occurrences over the past four and a half centuries. *J. Geophys. Res*., 92: 14449–14461.

Ricker, W.E. 1954. Stock and recruitment. *J. Fish. Res. Board Can*., 11: 559–623.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. *Bull. Fish. Res. Board Can.*, 191: 382 pp.

Royer, T.C. 1993. High Latitude Oceanic Variability Associated with the 18.6 Year Luni-Solar Tide, *Journal of Geophysical Research*, 84: 4639–4644.

Schaefer, M. 1954. Some aspects of the dynamics of populations important to the management of the commercial marine fisheries. *Bull. I-ATTC/Bol. CIAT*, 1(2): 27–56.

Sharp, G.D. 1979. Areas of potentially successful exploitation of tunas in the Indian Ocean with emphasis on surface methods. Indian Ocean Programme*, FAO, Rome, Tech. Reports* IOFC/DEV/79/47. 50pp.

Sharp, G.D. 1984. Ecological efficiency and activity metabolism. *In* M.J.R. Fasham, ed. *Flows of Energy and Materials in Marine Ecosystems*: *theory and practice,* pp. 459–474. Plenum Press. New York and London.

Sharp, G.D. 1992. Climate Change, the Indian Ocean Tuna Fishery, and Empiricism. *In* M.H. Glantz, ed. *Climate Variability, Climate Change and Fisheries,* pp. 377–416. Cambridge University Press.

Sharp, G.D. 1995. Arabian Sea Fisheries and Their Production Contexts. *In* Thompson & Tirmizi, eds. *Arabian Sea Oceanography and Fisheries*, pp. 239–264. Karachi, Pakistan.

Sharp, G.D. 1997. Its About Time: Rethinking fisheries management. pp. 731–736. *In* Developing and Sustaining World Fisheries Resources: The state of science and management. Hancock, Smith, Grant and Beumer, eds. CSIRO, Australia.

Sharp, G.D. & McLain, D.R. 1993a. Comments on the global ocean observing capabilities, indicator species as climate proxies, and the need for timely ocean monitoring. *Oceanogr*., 5(3): 163–168.

Sharp, G.D. & McLain, D.R. 1993b. Fisheries, El Niño-Southern Oscillation and upper-ocean temperature records. *Oceanogr.,* 6(1): 13–22.

Shen, G.T. & Dunbar, R.B. 1995. Environmental controls on uranium in reef corals. *Geochim. Cosmochim. Acta,* 59: 2009–2024.

Shen, G.T., Boyle, E.A. & Lea, D.W. 1987. Cadmium in corals as a tracer of historical upwelling and industrial fallout. *Nature*, 328: 794–796.

Smith, P.E. & Moser, G.H. 1988. CalCOFI time series: an overview of fishes. *CalCOFI Rep*. XXIX: 66–90.

Sparre, P. & Venema, S.C. 1998. Introduction to tropical fish stock assessment. Part 1. Manual. *FAO Fisheries Technical Paper* No. 306.1, Rev. 2. Rome, FAO. 407 pp.

Ueber, E. & MacCall, A. 1992. The rise and fall of the California sardine empire. *In* M.H. Glantz, ed. *Climate Variability, Climate Change and Fisheries*, pp. 31–48. Cambridge University Press, Cambridge.

Wooster, W.S. & Fluharty, D.L. eds. 1984. *El Niño North*: *Niño Effects in the Eastern Subarctic Pacific Ocean.* Wash. Sea Grant, University of Washington, Seattle. 312 pp.

Web Pages and URLs that contain relevant information about climate and fisheries issues:

Start with: http://sharpgary.org and scan the various topics and links.

AFS Climate & Fisheries Symposium: “Fisheries in a Changing Climate”. 2001.
http://www.fisheries.org/climate/climate_symposium.htm

AGU Solar Variability and Climate Change – A Historical Overview, T.S. Feldman
http://www.agu.org/history/sv/articles/ARTL.html

Antigua and Barbuda. 2000.
http://www.cpacc.org/antbar_pg.htm

Arctic Climate Issues, essay by N. Bond, J. Overland and N. Soriede. 2000.
http://www.arctic.noaa.gov/essay_bond.html

Atlantic Climate Change Program
http://www.aoml.noaa.gov/phod/accp/

Causes of Climate Change – Basics
http://www.geog.ouc.bc.ca/physgeog/contents/7y.html

Charles Perry, USGS
http://ks.water.usgs.gov/Kansas/climate/

Climate Change and Impact on US Water Resources:
http://www.pacinst.org/CCBib.html

Climate Change and Salmon Stocks (see oversell of Most Alarming Consequences, etc.). 1999.
http://www.fish.bc.ca/conferences/oct_1999/cover.html

The Role of Convection in Global Climate (Kininmonth & Sharp
http://sharpgary.org/UnConvectGCM.html

Coping With Climate Change, Based on Historical Experiences. 2000. G.D. Sharp.
http://www.vision.net.au/~daly/sharp.htm

Coral Bleaching, Coral Mortality, and Global Climate Change. Rafe Pomerance. 1999.
http://www.state.gov/www/global/global_issues/coral_reefs/990305_coralreef_rpt.html

David Welch’s salmon threat hypothesis: Welch/map
http://sts.gsc.nrcan.gc.ca/adaptation/sensitivities/map5.htm

Doug Hoyt's Solar Climate Projection:
http://users.erols.com/dhoyt1/annex1.htm
http://users.erols.com/dhoyt1/bio.htm

Ed Mercurio's Review of the roles of Galactic Cosmic Waves in Erath's Climate
http://www.hartnell.cc.ca.us/faculty/mercurio/download.html

El Niño/La Niña Forecasting Made Good by Theodore Landscheidt
http://sharpgary.org/landscheidt.html
http://www.vision.net.au/~daly/sun-enso/sun-enso.htm

Fisheries and Biology of the Indian Ocean. J-L LeBlanc. 2001.
http://indianocean.free.fr/fish.htm

Fisheries and Climate Change: The Danish Perspective. 2000.
http://www.dmi.dk/f+u/publikation/dkc-publ/klimabog/CCR-chap-19.pdf

Fleet Numerical Oceanography and Meteorlogical Center – Global Ocean Updates
See OTIS links for Now-Casts of World Ocean
http://www.fnoc.navy.mil/PUBLIC/

Fred Oliver Beware of Global Cooling
http://www.vision.net.au/~daly/cooling.htm

Global Temperature Trend Calculator
http://www.co2science.org/temperatures/ghcn.htm>

GISP Global Station Surface Temperature Data:
http://www.giss.nasa.gov/data/update/gistemp/station_data/

Guest papers
http://www.vision.net.au/~daly/guests.htm

Impacts of Climate Change and Fishing on Pacific Salmon Abundance over the Past 300 Years. B. Finney and others. Science, 27 October 2000.
http://www.uaf.edu/seagrant/NewsMedia/00news/10-20-00_Finney.html

International Earth's Rotation Service – -LOD or Rotation Rate indices
http://www.iers.org/iers/

T. Kawasaki's review of state of knowledge of Climate-Fisheries:
http://www.icsu-scope.org/downloadpubs/scope27/chapter06.html

Implications of Climate Change for Fisheries Management. Gunnar Knapp. 2001.
http://www.orst.edu/Dept/IIFET/2000/abstracts/knapp2.html

International Earth Rotation Service
http://www.iers.org/

IPCC Regional Impacts: Fisheries and other related activities. 2001.
http://www.grida.no/climate/ipcc/regional/299.htm

IPCC Report, 1995. Chapter 16, Climate Change 1995 Fisheries: Executive Summary – John T. Everett, USA
http://www.st.nmfs.gov/st2/climatec.htm

JISAO Climate and Ocean Science Resources
http://tao.atmos.washington.edu/science2.html

Jonathan Adams' Global land environments since the last interglacial
http://www.esd.ornl.gov/projects/qen/nerc.html

John Daly – Waiting for Greenhouse
http://www.vision.net.au/~daly/

Jean_Lu LeBlanc's Indian Ocean Fisheries and Oceanography website:
http://indianocean.free.fr/

Latent Heat Flux Imagery
http://www.icess.ucsb.edu/esrg/lh/latent_heat_flux.html

Long-term Climate Trends and Salmon Population. George Taylor. 1997.
http://www.ocs.orst.edu/reports/climate_fish.html

NAO: http://www.ldeo.columbia.edu/NAO/
http://www.cgd.ucar.edu/~jhurrell/PaperCopy/naobook.ch1.pdf

NAO Forecasting:
http:/www.john-daly.com/theodor/naonew.htm

NOAA Pacific Fisheries Environmental Laboratory website:Climate and Marine Fisheries
http://www.pfel.noaa.gov/research/climatemarine

Ocean Climate and Regime Shifts Bibliography:
http://www.cqs.washington.edu/crisp/ocean/ocean.html

Ocean Climate/ENSO Forecasts:
http://www.cqs.washington.edu/crisp/rel/ocean.html

Pål Brekke's recent Presentations on NASA/SOHO and Solar Influences – and Imagery
http://zeus.nascom.nasa.gov/~pbrekke/presentations/talks.html
http://folk.uio.no/paalb/research.html

Pangloss Fndtn Ocean calculator
http://www.dnai.com/~patwilde/ocean.html

PDO: http://www.jisao.washington.edu/pdo

Selected Bibliographies
http://www.pfel.noaa.gov/research/climatemarine/cmfpublications/cmfpublications.html#BIBLIO

Sherwood and Kieth Idso's CO2 Science website:
http://www.co2science.org/

Solar Influences and Commentary by Doug Hoyt:
http://users.erols.com/dhoyt1

SPC Ocean Fisheries Links;
http://www.spc.org.nc/coastfish/links.html

Sudden climate transitions during the Quaternary. Progress in Physical Geography. Jonathan Adams, Mark Maslin, Ellen Thomas. 1999.
http://www.esd.ornl.gov/projects/qen/transit.html

Taylor Dome Ice Laminae Climate Record
http://depts.washington.edu/isolab/taylor

The Great Climate flip-flop. William Calvin. 1998.
http://faculty.washington.edu/wcalvin/1990s/1998AtlanticClimate.htm

The Pleistocene and the Origins of Human Culture: Built for Speed.
Peter J. Richrason and Robert Boyd. 1998.
http://www.des.ucdavis.edu/faculty/Richerson/Speed.htm

UN Atlas of the Oceans:
http://www.oceansatlas.org/index.jsp

UN Framework Convention on Climate Change – Climate Change Information Kit:
http://www.unfccc.de/resource/iuckit/fact10.html

Understanding and Predicting Global Climate Change Impacts on the Vegetation and Fauna of Mangrove Forested Ecosystems in Florida. USGS. 2000.
http://www.nrel.colostate.edu/brd_global_change/proj_29_florida_mangroves.html

Workshop: Climate Change and the Great Lakes: What Are the Potential Impacts, and What Can We Do? EPA. 2001.
http://www.epa.gov/glnpo/climate/workshops.html

ANNEX II

GLOSSARY

Atmospheric Climate Indices – (ACI): characterizes the large-scale (hemispheric) air mass transfer that can be classified into three main components by a predominant direction of the air mass transport: "meridional" (C), "western" (W) and "eastern (E). According to their names, (C) component indicates predominant air transport from North to South and back, while (W) and (E) components indicate predominant West–East and East–West air transport The Atmospheric Circulation Index was suggested by Vangeneim (1940) and Girs [1971] to characterize atmospheric processes on a hemispheric (global) scale.

Condensation: the change of water vapour into a liquid. In order to condense water vapour, the air must be at or near saturation in the presence of condensation nuclei.

Condensation nucleus: a particle, liquid or solid, upon which condensation of water vapour begins in the air, i.e. dust, salt, water droplet, etc.

Continental climate: characterizes the interior of a large land-mass, marked by large annual, day-to-day, or day/night temperature ranges; low relative humidity; and moderate to low irregular rainfall. Annual temperature extremes occur soon after the solstices. (See maritime climate)

Coriolis force: the deflection of moving objects (air and water currents) due to the rotation of the Earth – to the right in the northern hemisphere, and to the left in the southern – important in the formation of anticyclones, cyclones, gyres, eddies.

Cyclone: an area of low pressure, with circulation counterclockwise in the northern hemisphere and clockwise in the southern hemisphere.

Doldrums: The narrow, low-pressure belt centred on the equator, characterized by light, variable winds, rising air currents, and heavy rainfall.

El Niño, Southern Oscillation (ENSO): an interannual see-saw in tropical sea-level pressure between the eastern and western hemispheres. During El Niño, unusually high atmospheric sea-Level pressures develop in the western tropical Pacific and Indian Ocean regions, and unusually low sea-level pressures develop in the southeastern tropical Pacific. So tendencies for unusually low pressures west of the date line and high pressures east of the date line have also been linked to periods of anomalously cold equatorial Pacific sea-surface temperatures sometimes referred to as La Niña.

Geoid: the baseline figure of the Earth, considered as a sea-level surface including local gravitational effects, without accounting for topographic features, and extended over the entire Earth's surface.

Geostrophic velocity vectors: Ocean currents are a function of wind forcing, the Earth's rotation, tidal forcesand movement of water from areas of higher water levels (pressure) to lower water levels (pressure). The component of the current that is caused by watermoving from areas of higher pressure to lower pressure is known as the geostrophic velocity vector. In some regions most of the current is geostrophic current.

Infrared radiation: electromagnetic radiation comprising wavelengths between 0.75 and 1000 mm that occupies that part of the electromagnetic spectrum with a frequency less than that of visible light and greater than that of most radio waves, although there is some overlap. The name infrared means "below the red," i.e., beyond the red, or lower frequency (longer wavelength), end of the visible spectrum. Infrared radiation is thermal, or heat, radiation.

Intertropical Convergence Zone (ITCZ): nearly solid ring of thunderstorms surrounding the globe in the tropics as easterly trades of both hemispheres converge at equator.

Maritime climate: characterizes oceanic islands or coastal regions of continents, marked by small annual, day-to-day, or day/night temperature ranges; high relative humidity; and regular rainfall. Annual temperature extremes lag after the solstices. (See continental climate).

Mediterranean Climate: mid-latitude climate found on the western coasts of continents, characterized by mild, rainy winters and dry summers.

Ocean season: seasonal change in sea-level height caused by change in heat content and prevailing winds.

Ocean tide: effect of lunar and solar gravity on mid-ocean water. Pacific Decadal Oscillation (PDO) long-term (20 to 30 years) fluctuation in sea-surface heights/ocean temperature along eastern/western coasts of the Pacific Ocean.

Milankovitch Cycles: The first of the three Milankovitch Cycles is the Earth's eccentricity. Eccentricity is, simply, the shape of the Earth's orbit around the Sun, a constantly fluctuating orbital shape ranges between 0 to 5% ellipticity on a cycle of about 100,000 years;

- The second is Axial tilt: the inclination of the Earth's axis in relation to its plane of orbit around the Sun. Earth's axial tilt oscillations range from 21.5 to 24.5 degrees with a periodicity of 41,000 years;

- The third of the Milankovitch Cycles is Earth's precession. Precession or slow wobble as it spins on axis. This wobbling can be likened to a top running down, that begins to wobble back and forth on its axis. The precession of Earth wobbles from pointing at Polaris (North Star) to pointing at the star Vega. When this shift to the axis pointing at Vega occurs, Vega would then be considered the North Star. This precession, has a periodicity of 23,000 years.

North Atlantic Oscillation (NAO): The NAO index is often defined as the difference of sea-level pressure between two stations situated close to the "centres of action" over Iceland and the Azores. Stykkisholmur (Iceland) is invariably used as the northern station, whereas either Ponta Delgada (Azores), Lisbon (Portugal) or Gibraltar are used as the southern station. The NAO has strong impacts on weather and climate in the North Atlantic region and surrounding continents and is a dominant exogenous factor in many ecological systems.

Pacific Decadal Oscillation (PDO): long-term (20 to 30 years) fluctuation in sea-surface heights/ocean along eastern/western coasts of the Pacific Ocean.

Rossby waves: an extraordinarily slow westward-moving ocean wave of low amplitude (10 to 20 centimeters) and great width (hundreds of kilometers) that crosses the Pacific over several decades.

Scatterometer: a microwave (radar) sensor that scans the surface of the earth from an aircraft or satellite and reads the reflection or scattering coefficient of the return pulse to measure surface roughness and derive wind speed and direction.

Sea level anomaly: the difference between the actual, measured sea level height and a mean sea level based on a mathematical reference. See geoid, reference ellipsoid, reverse barometer.

Sea level height: the actual, measured height of sea level against a standard reference. See geoid, reference ellipsoid, sea level anomaly.

Seasat: JPL-designed Earth-orbital mission, launched in 1978, to flight-test five instruments(a synthetic aperture radar, a radar altimeter, a scatterometer, a scanning multichannel microwave radiometer, and a visible and IR radiometer) to study the ocean surface; important legacy for many later Earth-orbiting instruments developed at JPL.

Sea surface height: Sea surface height is defined as the distance of the sea surface above the reference ellipsoid. The sea surface height is computed from altimeter range and satellite altitude above the reference ellipsoid. The "reference ellipsoid" is the first-order definition of the non-spherical shape of the Earth as an ellipsoid of revolution with equatorial radius of 6378.1363 kilometers and a flattening coefficient of 1/298.257. Also, the variable height of the sea surface above or below the geoid. Sea surface height is often shown as a sea-surface anomaly or sea-surface deviation, this is the difference between the sea surface height at the time of measurement and the average sea surface height for that region and time of year.

Southern Oscillation Index: an interannual see-saw in tropical sea-level pressure between Darwin Australia and Tahiti, the developmental history of which is described fully in Allan *et al*. 1996. Positive values indicate non-El Niño patterns, while negative values indicate pending or ongoing Warm Events.

Subsidence: for air, sinking, usually over a broad area, with associated increase in air pressure and rise in temperature.

Temperate climate: Characterizes mid-latitude regions with hot summers and cold winters.

Temperate zone: The mid-latitude climatic zone stretching from the tropic of Cancer to the arctic circle or from the tropic of Capricorn to the Antarctic circle and characterized by hot summers and cold winters.

TOPEX/Poseidon: Joint US-French orbital mission, launched in 1992 to track changes in sea-level height with radar altimeters.

Topography: The shape of a surface, including its relief and the relative position of features – the general configuration of a surface, including its relief.

Tropical zone: The low-latitude climatic zone centred on the equator, extending between the tropics of Cancer and Capricorn, and characterized by year-round hot weather.

Water vapour: the gaseous phase of water.

Weather: The short-term state of the atmosphere at a specific site with respect to temperature, humidity, wind speed and direction, clarity, and cloud cover. Refers to short-term events.