or on large-scale models, with a resolution too coarse to resolve the mesoscale structures such as upwelling that occurs over the continental shelf. As a consequence, these analyses tend to submerge indications of the coastal response within those of the adjacent larger-scale oceanic environment. For example, an analysis of SST and wind along the coastal shelf off West Africa indicated that the link between ENSO and this part of the Atlantic ocean is far stronger than previously thought (Roy and Reason, 2001).

Surprisingly, the impact of large-scale climate variability on the ecology of coastal ecosystems is quite often better known than the impact on the coastal marine physical components. For example, there is a abundant literature on the impact of the 1982-1983 and 1997-1998 El Niño episodes on the marine biota and resources of California and Peru but much less is known on the El Niño impact on the local physical processes (see for example, the volume "Pacific Climate Variability and Marine Ecosystems Impacts" (McKinnell et al. 2001a)).

A comparative research focus on the impact of the dominant large-scale climatic signals on coastal ecosystems might be particularly relevant from a socio-economic perspective. A good candidate for a pilot study would be the eastern boundary regions of the Pacific and Atlantic oceans where atmospheric forcing plays a dominant role in controlling key ecosystem processes such as coastal upwelling. It could start by investigating the local signature of the major climatic signals in atmospheric forcing fields as well as at the oceanic boundaries of the coastal regions. This can be done using historical time series as well as output from basin-scale atmospheric and oceanic models. A next step would be to implement higher-resolution regional-scale coastal models over the continental shelf. These models, forced at their boundaries by atmospheric and oceanic signal may provide particularly efficient tools for exploring the response of the dynamics and structure of coastal ecosystems to major basin-scale (or global) climatic signals (Penven et al. 2001, Marchesiello et al. 2002).

15 *Sardine regimes and mesoscale structure (an integrative hypothesis)* *[Alec MacCall]*

An Hypothesis Explaining Biological Regimes in Sardine-producing Pacific Boundary Current Systems (South America, North America and Japan): Implications of Alternating Modes of Slow, Meandering Flow and Fast Linear Flow in the Offshore Region

Introduction and acknowledgement

Because this hypothesis is the product of a workshop and draws on ideas contributed by a long list of excellent scientists, it seems appropriate to begin rather than end with some acknowledgments. The following hypothesis was developed while participating in the Boundary Current - Frontal Systems Working Group at the Pacific Climate and Fisheries Workshop, held November 14-17, 2001 at the East-West Center, University of Hawaii. Especially notable is the contribution of Takashige Sugimoto, who originally described most aspects of this hypothesis for the Japanese ecosystem. The contribution I made was to generalize and extend his hypothesis to the other Pacific boundary current systems. Don Olson provided an oceanographer's insight as to how flow conditions in these three systems might be linked. Other scientists who were not at the workshop (e.g., Richard Parrish of the Pacific Fisheries Environmental Laboratory, Pacific Grove, Paul Smith of the Southwest Fisheries Science Center, La Jolla, and Daniel Lluch-Belda of the Centro Interdisciplinario de Ciencias Marinas, La Paz) have nonetheless contributed significantly to development of the hypothesis. Finally, a major acknowledgement goes to Andrew Bakun, who not only convened this workshop, but also provided the foundation for these ideas through his extensive work on the oceanography of pelagic fish reproduction.

15.1 Outline of the flow-based hypothesis

The major sardine-producing systems have two distinct pelagic habitats, a nearshore coastal habitat and an offshore boundary current habitat. The characteristic long-term patterns of biological variability in these systems are associated with inter-decadally alternating strong and weak modes of

boundary current flow and related reproduction-related physics of the nearshore and offshore habitats, and from habitat switching by the larger species (i.e., sardines, but not anchovies) to utilize the offshore habitat when conditions are favorable. Under conditions of slow, meandering boundary current flow, retention of eggs and larvae spawned in the offshore habitat is greater than under conditions of fast, straight flow.

15.2 Fish behavior: habitat switching

Some species such as anchovies (*Engraulis* spp.) and juvenile coho salmon (smolts of Oncorhynchus kisutch) are restricted to the coastal habitat, probably because of their small size and limited swimming ability. Other generally larger species such as sardines (*Sardinops* spp.), mackerel (*Scomber japonicus*) and horse mackerel (*Trachurus* spp.) are able to utilize both nearshore and offshore habitats, and switch between nearshore and offshore habitats according to their relative favorability for feeding and reproduction. The evidence for habitat switching by populations of the larger pelagic species varies among geographic regions. During their recent increase of sardine abundance in the Japanese system, the population clearly expanded into far offshore regions associated with the Kuroshio Current (Wada and Kashiwai 1989). In the California Current, the far offshore region has not been well sampled even by the CalCOFI ichthyoplankton surveys, especially after the regime shift of 1976. Importantly, sardine eggs were collected 200 to 300 miles off California and Oregon in early ichthyoplankton surveys conducted in 1931 and 1939 during the earlier period of high sardine productivity (Smith 1990). In the early 1990s, the Russian trawler *Novodrutsk* conducted exploratory fishing for *Trachurus* 200 miles off the California coast and found unexpected abundances of *Sardinops* and *Scomber* in those offshore waters (D. Abramenkoff, NMFS La Jolla, personal communication). Recent sardine egg surveys using the Continuous Underway Fish Egg Sampler provide improved offshore monitoring (Checkley et al. 2000), but frequently fail to reach the offshore edge of the distribution.

Bakun's (1996) "fundamental triad" of enrichment, concentration and retention provides a framework for evaluating the suitability of inshore and offshore habitats. The role of enrichment in this hypothesis is unresolved, and may vary among systems (see below), but the meandering patterns associated with weaker boundary current flow have clear implications for concentration and retention. Of the elements of the triad, variability in larval retention is by far the most important aspect of this hypothesis.

15.3 Physical and biological oceanography

The offshore boundary current tends to exhibit two alternative modes:

1. A fast transport mode, in which the current is relatively straight (reduced motion perpendicular to the main flow).

2. A slow transport mode, in which the current meanders (increased motion perpendicular to the main flow) and has complicated structure, a relatively large frontal area, and greater tendency to form persistent mesoscale eddies.

Note that temperature anomalies associated with flow strength are governed by the source water temperature: The slow, meandering mode is associated with warming in the California and Peru Currents which have high latitude sources, but a slowing of the Kuroshio system produces a cooling because of its tropical source. In the eastern Pacific systems, the slow meandering mode characteristic of warm regimes may also occur during El Niño events embedded within cool regimes (e.g., the El Niño of 1957-58 off California, during which sardines experienced two years of good reproduction in a decade that otherwise showed consistent recruitment failures). It is hypothesized that with the exception of El Niño perturbations, these boundary currents tend to stay in the same flow mode for periods of many years, and then switch suddenly to the opposite mode in a so-called "regime shift".

Logerwell and Smith (2001) have shown that offshore mesoscale eddies in the California Current are associated with significantly elevated densities of sardine larvae. Logerwell et al. (2001) modeled the spatial bio-energetics of such an offshore eddy, and concluded that they are likely to be a significant source of sardine recruitment. An important unanswered

question is whether the hypothesized decreased current velocity and increased meandering associated with the slow-flow current is sufficient to improve retention of sardine larvae, or whether the flow must form persistent eddies with closed circulation and well-developed structure for sardine populations to increase. In either case, the extent of meandering and/or eddy formation is presumed to be enhanced during periods of weaker boundary current flow.

Modes of boundary current flow exhibit regional variations that may explain regional differences in nutrient patterns. Richard Parrish (NMFS Pacific Fisheries Environmental Laboratory, personal communication) has shown that the post-1976 slow mode of the California Current drew nutrient-poor water from the equatorward side of the North Pacific transition zone, whereas the pre-1976 fast mode drew richer water from a higher latitude. Parrish's mechanism helps explain the post-1976 decline in plankton volumes seen in the California Current (Roemmich and McGowan 1995); a similar mechanism in the southern hemisphere could explain the parallel decline in plankton abundance off Peru reported by Carrasco and Lozano (1989). Plankton volumes should be interpreted with caution, as they include gelatinous forms and do not necessarily reflect trends in abundance of zooplankton that would serve as forage (Smith 1985). In contrast to the eastern Pacific systems, the slow-flow mode of the Kuroshio system may experience an enrichment due to increased intrusion of nutrient-rich Oyashio Current water, as happened during the mid-1980s, ending suddenly in1988 (Sugimoto et al. 2001).

Differences in nearshore oceanography associated with these flow modes is less clear. In the Eastern Pacific systems, coastal upwelling and nutrient enrichment may be somewhat stronger during fast flow modes, but substantial coastal upwelling also occurs during slow flow modes. However, the reduction in nutrients and the deeper thermocline depths associated with the warm, slow flow mode in the Eastern Pacific systems may reduce nutrient enrichment associated with coastal upwelling under those conditions. The convoluted island and shoreline topography of the Japanese coastal ecosystem contrasts strongly with the linear, exposed coastline of the Eastern Pacific systems, and may provide resident fishes with good nearshore egg and larval retention during periods of fast Kuroshio Current flow.

15.4 Synchrony and teleconnections

At the decadal scale, a general synchrony of regime shifts in the various Pacific coastal boundary currents has been observed (Kawasaki 1983, 1989), but at finer time scales this synchrony is only approximate. Interdecadal variability in intensity of the major North and South Pacific gyres appears to be linked through hemispheric and global atmospheric circulation so that changes of intensity of both gyres are approximately in phase. In the recent record, the major unexplained departure from synchrony is the apparent time lag of about one decade in the California Current relative to the Japanese and Peruvian systems (MacCall 1996).

Trachurus benefits from attaining a larger size before individuals migrate to the cold and energetically demanding offshore and high latitude waters. A detailed demographic comparison of life-histories and habitat preferences for these characteristic boundary current species would be useful. There may be an opportunity for more detailed predictability of abundance fluctuations in the full list of pelagic species, and not only sardines and anchovies.

15.5 Concluding thoughts

In previous efforts to understand "the regime problem" (e.g., Schwartzlose et al. 1999) we have been distracted by temperature relationships evident in the eastern Pacific systems (i.e., warm conditions favor sardine productivity), and have tended to think of the Japanese system (in which cold conditions are associated with sardine productivity) as being different, and requiring a different explanation. By acknowledging that temperature anomalies are primarily the result of flow patterns, and that reproductively important aspects of species ecology and life history are more closely associated with properties of the flow itself, this hypothesis unifies our understanding of the three major boundary current systems in the Pacific.

We have also been distracted by habitat selection theories such as the basin model (MacCall 1990) and the ideal free distribution selection (Wada and Kashiwai 1989). These models suggested that the offshore expansion of the sardine spawning grounds (considered as "effect") is in response to the increase in abundance (considered as "cause"). This new

flow-based hypothesis reverses the interpretation of cause and effect, so that the improvement of offshore spawning habitat (now the "cause") leads to improved reproduction and increased abundance (now the "effect"). However, the flow-based hypothesis is not exclusive of the previous habitat selection theories, and there may well be habitat selection effects within the nearshore and offshore systems. This is consistent with the geographic expansion of sardine spawning within the southern California Bight during the increasing abundances of the late 1980s (Barnes et al. 1992, Smith 1990). MacCall's basin model may be best suited to the anchovy (for which it was originally developed), the species that is least able to switch between nearshore and offshore habitats.

Table 2. Comparison of Pacific Ocean coastal ecosystem properties under weak and strong modes of boundary current flow.

Mode of current flow	Weak, slow flow	Strong, fast flow
Coastal sea level	Higher	Lower
Water motion	Enhanced meandering	Reduced meandering
Frontal area	Increased	Decreased
Offshore larval retention	Favorable	Unfavorable
Temperature anomaly		
Eastern Pacific	Warm	Cool
Japan	Cool	Warm
Nutrient supply		
Eastern Pacific	Reduced (lower lat. source)	Enhanced (higher lat. source)
Japan	Enhanced (Oyashio intrusion)	Reduced
Sardine abundance	Increased	Decreased
Anchovy abundance		
California	Slight decrease	Slight increase
Peru/Chile	Strong decrease	Strong increase
Japan	Slight decrease	Slight increase

References

Agrawala, S. and K. Broad. 2002. Technology transfer perspective on climate forecast applications. Research in Science and Technology Studies 13, 45-69.

Alheit, J. and P. Bernal. 1993. Effects of physical and biological changes on the biomass yield of the Humboldt Current ecosystem. p. 53-68. In: K. Sherman, L. M. Alexander, and B. Gold (eds.) Large Marine Ecosystems—Stress, Mitigation, and Sustainability. American Association for the Advancement of Science.

Arntz, W. E., A. Landa and J. Tarazona. 1985. El Niño: Su impacto en la fauna marina. Bol. Inst. Mar., vol. ext., Perú-Callao, 222 pp.

Bakun, A. 1996. Patterns in the Ocean: Ocean Processes and Marine Population Dynamics. University of California Sea Grant, San Diego, California, USA, in cooperation with Centro de Investigaciones Biológicas de Noroeste, La Paz, Baja California Sur, Mexico. 323 pp.

Bakun, A. 1998. Ocean Triads and Radical Interdecadal Stock Variability: Bane and Boon for Fishery Management Science. pp. 331-358. In: T.J. Pitcher, P.J.B. Hart and D. Pauly (eds.) Reinventing Fisheries Management. Kluwer Academic Publishers, Dordrecht, Netherlands.

Bakun, A. 2001. 'School-mix feedback': a different way to think about low frequency variability in large mobile fish populations. Prog. Oceanogr. 49, 485-511.

Bakun A. 2002a. Seeking an expanded suite of management tools: implications of rapidly-evolving adaptive response mechanisms (such as "school-mix feedback"). In: N. Erhardt (ed.) Proceedings of the World Conference on Sustainable Fisheries. Center for Sustainable Fisheries, Univ. Miami (in review).

Bakun A. 2002b. An empirical test for the existence of a generation-time-dependent mechanism for rapid adaptive response of fish populations to variations in ocean climate, predation or fishery exploitation. pp. 2-4. In: C.D. Van der Lingen, C. Roy, P. Fréon, M. Barange, L. Castro, L. Gutierrez, L. Nykjaer and F. Shillington (eds.) Report of a GLOBEC-SPACC/IDYLE/ENVIFISH workshop on spatial approaches to the dynamics of coastal pelagic resources and their environment in upwelling areas. GLOBEC Rep. 16.

Bakun, A. and P. Cury. 1999. The "school trap": a mechanism promoting large-amplitude out-of-phase population oscillations of small pelagic fish species. Ecol. Letters 2, 349-351.

Bakun, A. and R. Parrish. 1980. Environmental inputs to fishery population models for eastern boundary currents. pp. 67-104. In: G.D. Sharp (ed.) Workshop on the effects of environmental variation on the survival of larval pelagic fishes. IOC Workshop Rep. 28., Intergovernmental Oceanographic Commission, UNESCO, Paris. 323p.

Barber, R. T. and F. P. Chavez. 1983. Biological consequences of El Niño. Science 222, 1203-1210.

Barnes, T., L. Jacobson, A. MacCall, and P. Wolf. 1992. Recent population trends and abundance estimates for the Pacific sardine (*Sardinops sagax*). Calif. Coop. Oceanic Fish. Invest. Rep. 33, 60-75.

Barrett, C. B. 1998. The Value of Imperfect ENSO Forecast Information: Discussion. Amer. J. Agricul. Econ. 80 (5), 1109-1112.

Beamish, R. J., and D. R. Bouillon. 1993. Pacific salmon production trends in relation to climate. Can. J. Fish. Aquat. Sci. 50, 1002-1016.

Beamish, R. J., C. E. M. Neville, et al. 1997. Production of Fraser River sockeye salmon (Oncorhynchus nerka) in relation to decadal-scale changes in the climate and the ocean. Can. J. of Fish. Aquat. Sci. 54, 543-554.

Beamish, R.J., D.J. Noakes, G.A. MacFarlane, L. Klyashtorin, V.V. Ivanov and V. Kurashov. 1999. The regime concept and natural trends in the production of Pacific salmon. Can. J. of Fish. Aquat. Sci. 56, 516-526.

Berkes, F., R. Mahon, P. McConney, R. Pollnac and R. Pomeroy. 2001. Managing Small-Scale Fisheries. Alternative Directions and Methods. International Development Research Centre, Canada. 320p.

Bertram, D.F., D.L. Mackas and S.M. McKinnell. 2001. The seasonal cycle revisited: interannual variation and ecosystem consequences, pp. 283-307 In: S.M. McKinnell, R.D. Brodeur, K. Hanawa, A.B. Hollowed, J.J. Polovina and C.-I. Zhang (eds.) Pacific Climate Variability and Marine Ecosystem Impacts. Prog. Oceanogr. 49.

Bradford, M. J., and J.R. Irvine. 2000. Land use, fishing, climate change, and the decline of Thompson River, British Columbia, coho salmon. Can. J. Fish. Aquat. Sci. 57, 13-16.

Brander, K.M. and P.C.F. Hurley. 1992. Distribution of early-stage Atlantic cod, (*Gadus morhua*), haddock (*Melanogrammus aegelfinus*) and witch flounder (*Glyptocephalus cynoglossus*) eggs on the Scotian Shelf: A reappraisal of evidence on the coupling of cod spawning and plankton production. Can. J. Fish. Aquat. Sci. 49, 238-251.

Brander, K.M., R.R. Dickson and J.G. Shepherd. 2001. Modelling the timing of plankton production and its effect on recruitment of cod (*Gadus morhua*). ICES J. Mar. Sci. 58, 962-966.

Broad, K., and S. Agrawala. 2000. The Ethiopia famine: Uses and limits of seasonal climate forecasts. Science 289, 1693-1694.

Broad, Kenneth, Alex Pfaff, and Michael H. Glantz (in press) Effective & Equitable Dissemination of Seasonal-to-Interannual Climate Forecasts: policy implications from the Peruvian fishery during El Niño 1997-98. Climatic Change.

Brodeur, R.D., and D.M. Ware. 1992. Long-term variability in zooplankton biomass in the subarctic Pacific Ocean. Fish. Oceanogr. 1, 32-38.

Brodeur, R.D., and D.M. Ware. 1995. Interdecadal variability in distribution and catch rates of epipelagic necton in the North Pacific Ocean. pp. 329-356. In Beamish, R.J., ed. Climate Change and Northern Fish Populations. Can. Spec. Publ. Fish. Aquat. Sci. 121.

Carr, M.-E. and K. Broad. 2000. Satellites, Society, and the Peruvian fisheries during the 1997-98 El Niño. pp. 171-191. In: D. Halpern (ed.) Satellites, Oceanography and Society. Elsevier Science, Amsterdam.

Carrasco, S. and O. Lozano. 1989. Seasonal and long-term variations of zooplankton volumes in the Peruvian Sea, 1964-1987. pp. 82-85. In: Pauly, D., P. Muck, J. Mendo, and I. Tsukayama, Eds. The Peruvian upwelling ecosystem: dynamics and interactions. ICLARM Conference Proceedings 18, 438p.

Chakravorty, U. 1997. "Optimal regulation of the Hawaii pelagic fishery: Proposal," Pelagic Fisheries Research Program, 1997-2002.

Chakravorty, U. and K. Nemoto. 2001. Modeling the effects of area closure and tax policies: A spatial-temporal model of the Hawaii longline fishery. Marine Resource Economics 15, 179-204.

Chakravorty, U. and J. Sibert, eds. 1999. Ocean-Scale Management of Pelagic Fisheries: Economic and Regulatory Issues, Joint Institute of Marine and Atmospheric Research Contribution 99-321, 102 pp.

Checkley, D., R. Dotson and D. Griffith. 2000. Continuous, underway sampling of eggs of Pacific sardine (*Sardinops sagax*) and northern anchovy (*Engraulis mordax*) in spring 1996 and 1997 off southern and central California. Deep-Sea Res. II 47, 1139-1155.

Cowen R., K.M.M. Lwiza, S. Sponaugle C.B. Paris and D.B. Olson. 2000. Connectivity of marine populations: open or closed? Science 287, 857-859.

Cury, P., and C. Roy. 1989. Optimal environmental window and pelagic fish recruitment success in upwelling areas. Can. J. Fish. Aquat. Sci. 46, 670-680.

Cury, P., C. Roy, R. Mendelssohn, A. Bakun, D.M. Husby, and R.H. Parrish. 1995. Moderate is better: nonlinear climatic effect on California anchovy (Engraulis mordax). pp. 417-424. In: R.J. Beamish (ed.). Climate Change and Northern Fish Populations. Can. Spec. Publ. Fish. Aquat. Sci. 121. 739 pp.

Cushing, D.H. 1969. Upwelling and fish production. FAO Fish. Tech. Pap. 84. 40pp.

Cushing, D.H. 1971. The dependence of recruitment on parent stock in different groups of fishes. J. Cons. int. Explor. Mer. 33, 340-362.

Cushing, D.H. 1975. Marine Ecology and Fisheries. Cambridge University Press, Cambridge. 278p.

Cushing, D.H. 1990. Plankton production and year-class strength in fish populations: an update of the match/mismatch hypothesis. Adv. Mar. Biol. 26, 249-293.

Dagorn, L. and P. Freon. 1999. Tropical tuna associated with floating objects: a simulation study of the meeting point hypothesis. Can. J. Fish. Aquat. Sci. 56, 984-993.

Durand, M.-H., P. Cury, R. Mendelssohn, C. Roy, A. Bakun and D. Pauly (eds.) 1998. Global Versus Local Changes in Upwelling Systems. ORSTOM Editions, Paris. 594 pp.

Ebbesmeyer, C.C., D.R. Cayan, D.R. McLain, F.H. Nichols, D.H. Peterson, and K.T. Redmond, 1991. 1976 step in the Pacific climate: forty environmental changes between 1968-1975 and 1977-1984. In: J. Betancourt and V.L. Tharp (eds.) Proc. 7th Annual Pacific Climate Workshop. Calif. Dept Water Resources, Interagency Ecol. Stud. Prog. Tech. Rep. 26, 129-141.

FAO. 2001. Research implications of adopting the precautionary approach to management of tuna fisheries. FAO Fish. Circ. 963. 88 pp.

Fortier, L., D. Ponton and M. Gilbert. 1995. The match/mismatch hypothesis and the feeding success of fish larvae in ice-covered southeastern Hudson Bay. Mar. Ecol. Prog. Ser. 120, 11-27.

Fournier,D.A., J. Hampton and J.R. Sibert. 1998. MULTIFAN-CL: a length-based, age-structured model for fisheries stock assessment, with appliacation to South Pacific albacore, *Thunnus alalunga*. Can. J. Fish. Aquat. Sci. 55, 2105-2116.

Fry, B. 1988. Food web structure on Georges Bank from stable C, N, and S isotopic compositions. Limnol. Oceanogr. 33, 1182-1190.

Gargett, A.E. 1997. The optimal stability 'window': a mechanism underlying decadal fluctuations in North Pacific salmon stocks? Fish. Oceangr. 6, 109-117.

Glantz, M.H. 1979. Science, politics, and economics of the Peruvian anchovy fishery. Marine Policy, July, 1979, 201-210.

Glantz, M.H. 1986. Man, state, and fisheries: An inquiry into some societal constraints that affect fisheries management. Ocean Development and International Law 17, 191-270.

Glantz, M.H. (ed.) 1995. Usable Science II: The Potential Use and Misuse of El Niño Information in North America. NCAR, 260 pp.

Glantz, M.H. 1996 (2001). Currents of Change: El Niño's impact on climate and society. Cambridge Univ. Press, 194 pp.

Glantz, M.H. and J.D. Thompson (eds.) 1981. Resource Management and Environmental Uncertainty: Lessons from Coastal Upwelling Fisheries. John Wiley and Sons, New York.

Gotceitas, V., V. Puvanendran, L.L. Leader and J.A. Brown. 1996. An experimental investigation of the 'match/mismatch' hypothesis using larval Atlantic cod. Mar. Ecol. Prog. Ser. 130, 29-37.

Graham, N.E. 1994. Decadal-scale climate variability in the 1970s and 1980s: observations and model results. Climate Dyn. 10, 135 162.

Hamnett, M.P. and C.L. Anderson C.L. 1998. Impact of Climate Variability on Pelagic Fisheries in the Pacific Islands. NOAA Office of Global Programs Progress Report, April 1998. Social Science Research Institute, Univ. Hawaii.

Hansen, J. W. (ed.) 2001. Forthcoming: Special Issue on Applying Seasonal Climate Prediction to Agriculture. Agricultural Systems.

Hanski I. 1991. Metapopulation dynamics: a brief history and conceptual domain. Biological J. Linn. Soc. 42, 3-16.

Hare, S. R. and N. J. Mantua. 2000. Empirical evidence for North Pacific regime shifts in 1977 and 1989. Prog. Oceanogr. 7, 103-145.

Hare, S. R., N. J. Mantua and R.C. Francis. 1999. Inverse production regimes: Alaska and West Coast Pacific salmon. Fisheries 24, 6-14.

Hare, S.R., S. Minobe, W.S. Wooster, and S. McKinnell. 2000. An introduction to the PICES symposium on the nature and impacts of North Pacific climate regime shifts. Prog. Oceanogr. 47, 99-102.

Hay, D.E., P.B. McCarter, and K.S. Daniel. 2001. Tagging of Pacific herring *Clupea pallasi* from 1936-1992: a review with comments on homing, geographic fidelity, and straying. Can. J. Fish. Aquat. Sci. 58, 1356-1370.

Hughey, KFD, R. Cullen and G.N. Kerr. 2000. Stakeholder groups in fisheries management. Marine Policy 24, 119-127.

Hurrell, J. W. and H. van Loon. 1997. Decadal variations in climate associated with the North Atlantic oscillation. Climatic Change 36, 301-326.

Jordán, R., J. Csirke and I. Tsukayama. 1978. Situacion de los recursos anchoveta, sardina, jurel y caballa al Junio 1978. Instituto del Mar del Peru, Informe No. 56. 32 p.

Jentoft, S. 2000. The community: A missing link of fisheries management. Marine Policy 24, 53-59.

Jentoft, S., B. J. McCay and D. C. Wilson. 1998. Social theory and fisheries management. Marine Policy 22, 423-436.

Kawasaki, T. 1983. Why do some pelagic fishes have wide fluctuations in their numbers? Biological basis of fluctuation from the viewpoint of evolutionary ecology. pp. 1065-1080 In: Sharp, G. D. and J. Csirke (eds.). Proceedings of the Expert Consultation to Examine Changes in Abundance and Species of Neritic Fish Resources. San Jose, Costa Rica, 18-29 April, 1983. FAO Fish. Rep. 291(2,3).

Kawasaki, T. 1989. Long-term variability in the pelagic fish populations. pp.47-60 In: T. Kawasaki, S. Tanaka, Y. Toba and A. Taniguchi (eds.), Long-term variability of pelagic fish populations and their environment. 402p.

Kifani, S. 1991. Approaches spatio-temporelle des relations hydroclimat-dynamique des espèces pélagiques en région d'upwelling: cas de la sardine du stock central marocain. Thèse de Doctorat, Spécialité Océanographie halieutique. Univ. Bret. Occid. 290 pp.

Kirby, D.S., O. Fiksen and P.J.B. Hart. 2000. A dynamic optimisation model for the behaviour of tunas at ocean fronts. Fish. Oceanogr. 9, 328-342.

Lasker, R. 1975. Field criteria for survival of anchovy larvae: the relation between inshore chlorophyll maximum layers and successful first feeding. Fish. Bull. U.S. 73, 453-462.

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

Lasker, R. 1981a. Factors contributing to variable recruitment of the northern anchovy (*Engraulis mordax*) in the California Current: Contrasting years 1975 through 1978. Rapp. P.-v. Réun. Cons. int. Explor. Mer. 178, 375-388.

Lasker, R. 1981b. The role of a stable ocean in larval fish survival and subsequent recruitment. p. 80-87. In: R. Lasker (ed.) Marine Fish Larvae: morphology, Ecology and Relation to Fisheries. Univ. Washington Press, Seattle. 131pp.

Legendre, L., and S. Demers. 1985. Auxiliary energy, ergoclines and aquatic biological production. Naturaliste can. Rev. Écol. Syst. 112, 5-14.

Lehodey, P. 2001. Sepodym skipjack analysis. 14th Standing Committee on Tuna and Billfish. Secretariat of the Pacific Community,Noumea, New Caledonia. Working Paper SKJ-2. 24 pp. (**http://www.spc.int/OceanFish/Html/TEB/Env/SKJ2.pdf**)

Lehodey, P. 2002. Impacts of the El Niño Southern Oscillation on tuna populations and fisheries. FAO, Rome. In press. (**http://www.spc.int/OceanFish/Html/TEB/Env/FAO_Paper.pdf**)

Lehodey, P., M. Bertignac, J. Hampton, A. Lewis, A. and J. Picaut. 1997. El Nino Southern Oscillation and tuna in the western Pacific. Nature 389, 715-718.

Lehodey, P., J-M. Andre, M. Bertignac, J. Hampton, A. Stoens, C. Menkes, L. Memery and N. Grima. 1998. Predicting skipjack tuna forage distributions in the equatorial Pacific using a coupled dynamical bio-geochemical model. Fish. Oceanogr. 7, 317-325.

Letson, D., I. Llovet, et al. 2001. User perspectives of climate forecasts: Crop producers in Pergamino, Argentina. Climate Res. 19, 57-67.

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

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

Loeb, V.J. and O. Rojas. 1988. Interannual variation of ichthyoplankton composition and abundance relations off northern Chile, 1964-83. Fish. Bull. U.S. 86 1-14.

Logerwell, E. and P. Smith. 2001. Mesoscale eddies and survival of late stage Pacific sardine (*Sardinops sagax*) larvae. Fish. Oceanogr. 10, 13-25.

Logerwell, E., B. Lavaniegos, and P. Smith. 2001. Spatially-explicit bioenergetics of Pacific sardine in the Southern California Bight: are mesoscale eddies areas of exceptional prerecruit production? Prog. Oceanog. 49, 391-406.

Louw, G.G., C.D.van der Lingen and M.J. Gibbons. 1998. Differential feeding by sardine *Sardinops sagax* and anchovy *Engraulis capensis* recruits in mixed shoals. S. Afr. J. mar. Sci. 19, 227-232.

Lu, H.-J., K.-T. Lee, and C.-H. Liao. 1998. On the relationship between El Niño/Southern Oscillation and South Pacific albacore. Fish. Res. 39, 1-7.

Lu, H.-J., K.-T. Lee, H.-L. Lin, and C.-H. Liao. 2001. Spatio-temporal distribution of yellowfin tuna, Thunnus albacares, and bigeye tuna, Thunnus obesus, in the tropical Pacific Ocean in relation to large temperature fluctuation during ENSO episodes. Fish. Sci. 67, 1046-1052.

MacCall, A.D. 1990. Dynamic Geography of Marine Fish Populations. University Washington Sea Grant Program, Seattle.158 pp.

MacCall, Alec D. 1996. Patterns of low frequency variability in fish populations of the California Current. Calif. Coop. Oceanic Fish. Invest. Rep. 37, 100-110.

Mackas, D.L., R.E Thomson and M. Galbraith. 2001. Changes in the zooplankton community of the British Columbia continental margin, 1985-1999, and their covariation with oceanographic conditions. Can. J. Fish. Aquat. Sci. 58, 685-702.

MacKenzie, B.R., T.J. Miller, S. Cyr and W.C. Leggett. 1994. Evidence for a dome-shaped relationship between turbulence and larval fish ingestion rates. Limnol. Oceanogr. 39, 1790-1799.

Mantua, N., S. Hare, Y. Zhang, J. Wallace, R. Francis. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. Bull. Am. Meteor. Soc. 78, 1069-1079.

Marchesiello P., J.C. McWilliams and A. Shchepetkin. 2002. Equilibrium structure and dynamics of the California Current System. J. Phys. Oceanogr. In press.

Mayr, E. 1982. The Growth of Biological Thought. Harvard Univ. Press, Cambridge, Mass. 974 pp.

McCay, B.J. and J. Acheson, 1987. The Question of the Commons: The Culture and Ecology of Communal Resources. Univ. Arizona Press. Tucson.

McCay, B.J. and Svein, J. 1996. From the bottom up: participatory issues in fisheries management. Society and Natural Resources 9, 237-250.

McGoodwin, J.R., 1990. Crisis in the World's Fisheries. Stanford Univ. Press.

McKinnell, S.M. 2001. 2001 coastal ocean/salmon ecosystem event. PICES Press Vol. 9 (2), 26-27.

McKinnell, S.M., R.D Brodeur, K. Hanawa, , A.B. Hollowed, J.J. Polovina and C.-I. Zhang (eds.) 2001a. Pacific Climate Variability and Marine Ecosystem Impacts. Prog. Oceanogr. 49. 639 pp.

McKinnell, S.M., C.C. Wood, D.T. Rutherford, K.D. Hyatt and D.W Welch. 2001b. The demise of Owikeno Lake sockeye salmon. N. Amer. J. Fish. Manage. 21, 774-791.

Mendelssohn, R., and P. Cury. 1987. Forecasting a fortnightly abundance index of the Ivoirian coastal pelagic species and associated environmental conditions. Can. J. Fish. Aquat. Sci. 44, 408-421.

Mendelssohn, R., and J. Mendo. 1987. Exploratory analysis of anchoveta recruitment off Peru and related environmental series. pp. 294-306. In: D. Pauly and I. Tsukayama (eds.) The Peruvian Anchoveta and Its Upwelling Ecosystem: Three Decades of Change. ICLARM Studies and Reviews 15. Instituto del Mar del Peru (IMARPE), Callao, Peru; Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), GmbH, Eschborn, Federal Republic of Germany; and International Center for Living Aquatic Resources Management (ICLARM), Manila, Philippines. 351pp.

Miller, A. J., and N. Schneider. 2000. Interdecadal climate regime dynamics in the North Pacific Ocean: Theories, observations and ecosystem impacts. Progr. Oceanogr. 47, 355-379.

Miller, A.J., D.C. Cayan, T.P. Barnett, N.E. Graham, and J.M. Oberhuber. 1994. Interdecadal variability of the Pacific Ocean: model response to observed heat flux and wind stress anomalies. Clim. Dyn. 9, 287 302.

Miller, K.A. 1996. Salmon stock variability and the political economy of the Pacific Salmon Treaty. Contemporary Economic Policy 14(3), 112-129.

Miller, K.A. 2000. Pacific salmon fisheries: Climate, information and adaptation in a conflict-ridden context. Climatic Change 45, 37-61.

Mjelde, James W. and K. Keplinger 1998. Using the Southern Oscillation to Forecast Texas Winter Wheat and Sorghum Crop Yields. J. Climate 11, 54-60.

Mjelde, J.W, H.S.J. Hill, and J. F. Griffiths. 1988. A review of current evidence on climate forecasts and their economic effects in agriculture. Amer. J. Agri. Econ. 80, 1089-1095.

Orlove, B.S. and J. Tosteson. 1998. The application of aeasonal to interannual climate forecasts based on El Niño-Southern Oscillation (ENSO) events: Lessons from Australia, Brazil, Ethiopia, Peru, and Zimbabwe. Institute of International Studies, University of California, Berkeley, WP 99-3.

Parrish, R.H., C. S. Nelson, and A. Bakun. 1981. Transport mechanisms and reproductive success of fishes in the California Current. Biol. Oceanogr. 1, 175-203.

Parrish, R.H., F.B. Schwing, and R. Mendelssohn. 2000. Mid-latitude wind stress: the energy source for climatic shifts in the North Pacific Ocean. Fish. Oceanogr. 9, 224-238.

Pauly, D. 1989. An eponym for Reuben Lasker. Fish. Bull. U.S. 87, 383-384.

Penven P., C. Roy, G.B. Brundrit, A. Colin de Verdière, P. Fréon, A.S. Johnson, J. R.E. Lutjeharms and F.A. Shillington. 2001. A regional hydrodynamic model of upwelling in the Southern Benguela. S. Afr. J. Sci. 97, 472-475.

Peterman, R.M., and M. J. Bradford. 1987. Wind speed and mortality rate of a marine fish, the northern anchovy (*Engraulis mordax*). Science 235, 354-356.

Peterson, W.T. and S.M. McKinnell. 2000. Ocean ecology of juvenile salmonids along the North American coast. PICES Press 8 (2), 25-26.

Pfaff, A., K. Broad and M. H. Glantz. 1999. Who benefits from climate forecasts? Nature 397, 645-646

Polovina, J.J, E. Howell, D.R. Kobayashi and M.P. Seki. 2001. The transition zone chlorophyll front, a dynamic global feature defining migration and forage habitat for marine resources. Prog. Oceanogr. 49, 469-483.

Polovina, J.J., G.T. Mitchum, N.E. Graham, M.P. Craig, E.E. DeMartini and E.N. Flint. 1994. Physical and biological consequences of a climate event in the central North Pacific. Fish. Oceanogr. 3, 15-21.

Pulwarty, R.S. and T.S. Melis. 2001. Climate extremes and adaptive management on the Colorado River: Lessons from the 1997-1998 ENSO event. J. Environ. Manag. 63, 307-324.

Pulwarty, R.S., and K.T. Redmond. 1997. Climate and Salmon Restoration in the Columbia River Basin: The Role and Usability of Seasonal Forecasts. Bull. Amer. Meteor. Soc. 78, 381-397.

Radovitch, J. 1979. Managing pelagic schooling prey species. In: Predator-Prey Systems in Fisheries Management. Sport Fishing Institute, Washington, D.C.

Rayner, S., M. Houk, et al., 1999. Institutional Issues in Adoption of Probabilistic Climate Variation Among US Water Managers. Society for Applied Anthropology 1999 Annual Meeting: Constructing Common Ground: Human and Environmental Imperatives, April 21-25, Tucson, AZ.

Roemmich, D., and J. A. McGowan. 1995. Climatic warming and the decline of zooplankton in the California Current. Science 267, 1324-1326.

Roncoli, C. (ed.) 2000. Anthropology and climate change: Challenges and contributions. Practicing Anthropology 22 (4 -special issue).

Rothschild, B.J. and T.R. Osborn. 1988. The effects of turbulence on planktonic contact rates. J. Plankton Res. 10, 465-474.

Roy, C. and C. Reason. 1991. ENSO related modulation of coastal upwelling in the eastern Atlantic. pp. 245-256. In McKinnell, S.M., R.D Brodeur, K. Hanawa, A.B. Hollowed, J.J. Polovina and C.-I. Zhang (eds.) Pacific Climate Variability and Marine Ecosystem Impacts. Prog. Oceanogr. 49.

Roy, C., P. Cury and S. Kifani, 1991. Optimal environmental window and pelagic fish reproductive strategies in upwelling areas. International Symposium on Benguela Trophic Functioning, Resource Utilization from an Ecosystem Perspective, Cape Town, South Africa, 8-13 Sep 1991.

Sarewitz, D., R.A. Pielke Jr. and R. Byerly Jr. (eds.) 2000. Prediction: Science, Decision Making, and the Future of Nature, Island Press, Washington, DC.

Schaefer, K.M. 1998. Reproductive biology of yellowfin tuna (Thunnus albacares) in the eastern Pacific Ocean. Bull. Inter-Am. Trop. Tuna Comm. 21(5), 201-272.

Schneider, N. and A.J. Miller. 2001. Predicting western North Pacific Ocean climate. J. Climate, 14, 3997-4002.

Schwartzlose, R., J. Alheit, A. Bakun, T. Baumgartner, R. Cloete, R. Crawford, W. Fletcher, Y. Green-Ruiz, E. Hagen, T. Kawasaki, D. Lluch-Belda, S. Lluch-Cota, A. MacCall, Y. Matsuura, M. Nevarez-Martinez, R. Parrish, C. Roy, R. Serra, K. Shust, and M. Ward, and J. Zuzunaga. 1999. Worldwide large-scale fluctuations of sardine and anchovy populations. S. Afr. J. Mar. Sci. 21, 289-347.

Serra, R. 1987. Impact of the 1982-83 ENSO on the Southeastern Pacific fisheries, with an emphasis on Chilean fisheries. pp. 24-29. In M. Glantz, R. Katz and M. Krenz (eds.) Climate Crisis: The Societal Impacts Associated with the 1982-83 Worldwide Climate Anomalies. NCAR/ESIG, Boulder, Colorado, 105 pp.

Serra, R. 1991. Long - term variability of the Chilean sardine. pp 165-172. In: T. Kawasaki, S. Tanaka, Y. Toba and A. Taniguchi (eds.) Proceedings of the International Symposium on the Long - Term Variability of Pelagic Fish Populations and their Environment. Pergamon Press, New York.

Serra, R., P. Cury and C. Roy. 1998. The recruitment of the Chilean sardine and the optimal environmental window. pp. 267-274. In: M. Durand, P. Cury, R. Mendelssohn, C. Roy, A. Bakun, D. Pauly (eds.) Global versus local changes in upwelling systems. ORSTOM Editions, Paris, 585 pp.

Sharp, G.D. and D.R. McLain. 1993. Fisheries, El Niño-Southern Oscillation and upper-ocean temperature records: An eastern Pacific example. Oceanography 6, 13-22.

Sinclair, M. 1988. Marine Populations. An essay on population regulation and speciation. Washington Sea Grant Program. Univ. Washington Press, Seattle and London. 252 p.

Smith, P.E. 1985. A case history of an anti-El Niño to El Niño transition on plankton and nekton distribution and abundances. pp 121-142 .In: W.S. Wooster and D.L. Fluharty (eds.) El Niño North: Niño Effects in the Eastern Subarctic Pacific Ocean. Washington Sea Grant Program, Univ. of Washington, Seattle.

Smith, P. 1990. Monitoring interannual changes in spawning area of Pacific sardine (*Sardinops sagax*). Calif. Coop. Oceanic Fish. Invest. Rep. 31, 145-151.

Steele, J.H. 1974. The stucture of marine ecosystems. Harvard Univ. Press, Cambridge, Mass. 128 p.

Stern, P.C., and W.E. Easterling. 1999. Making Climate Forecasts Matter. National Academy Press, 175 pp.

Sugimoto, T., S. Kimura and K. Tadokoro. 2001. Impact of El Niño events and climate regime shift on living resources in the western North Pacific. Prog. Oceanog. 49, 113-127.

Sverdrup, H.U. 1953. On conditions for vernal blooming of phytoplankton. J. Cons. int. Explor. Mer 18, 287-295.

Tarte, S. 2001. The international politics of tuna management in the Western and Central Pacific. Conference on People and the Sea, Amsterdam, 30 August – 2 September, 2001.

Tarte, S. 2002. Report on Pacific Climate and Fisheries Workshop, Honolulu, Hawaii, 14-17 November, 2001. Department of History/ Politics, University of the South Pacific, Suva, FIJI.

Tarazona, J. and E. Castillo. 1999. El Niño 1997-98 y su impacto sobre los ecosistemas marino y terrestre. Revista Peruana de Biología, Volumen Extraordinario, December 1999.

Thorrold, S.R., C. Latkoczy, P.K. Swart and C.M. Jones. 2001. Natal homing in a marine fish metapopulation. Science 291, 297-299.

Timmermann, A., J. Oberhuber, A. Bacher, M. Esch, M. Latif, and E. Roeckner. 1999. Increased El Niño frequency in a climate model forced by future greenhouse warming. Nature 398, 694-697.

Trenberth, K.E. and J.W. Hurrell. 1994. Decadal atmospheric-ocean variations in the Pacific. Clim. Dyn. 9, 303 319.

Venrick, E.L., J.A. McGowan, D.R. Cayan and T.L. Hayward. 1987. Climate and chlorophyl a: long-term trends in the Central North Pacific Ocean. Science 238, 70-72.

Walters, C.J. 1989. Value of short-term forecasts of recruitment for harvest management. Can. J. Fish. Aquat. Sci. 46, 1969-1976.

Wada, T. and M. Kashiwai. 1989. Changes in growth and feeding ground of Japanese sardine with fluctuation in stock abundance. pp.181-190 In: T. Kawasaki, S. Tanaka, Y. Toba and A. Taniguchi (eds.), Long-term variability of pelagic fish populations and their environment. 402p.

Ward, P., B. Kearney and N. Tsirbas, 2000. Science arrangements for the regional management of tuna fisheries. Marine Policy 24, 93-108.

Ware, D.M., and R.E. Thomson. 1991. Link between long-term variability in upwelling and fish production in the northeast Pacific Ocean. Can. J. Fish. Aquat. Sci. 48, 2296-2306.

Appendix 1.
List of Participants

Vera Agostini
School of Aquatic and Fishery Sciences
Box 355020
University of Washington
Seattle, WA 98190
tel: (206) 221-5461
vagostin@u.washington.edu

Jürgen Alheit
Baltic Sea Research Institute
Seestr. 15
18119 Warnemünde
Germany
tel: +49-381-5197 208
fax: +49-381-5197 440
juergen.alheit@io-warnemuende.de

Andrew Bakun
IRI-The International Research Institute
for Climate Prediction
NEW ADDRESS (after 1 July, 2002)
Center for Sustainable Fisheries
University of Miami, RSMAS
4600 Rickenbacker Causeway
Miami, FL 33149
abakun@rsmas.miami.edu

Kenneth Broad
Research Asst. Professor,
Div. of Marine Affairs & Policy
University of Miami, RSMAS
4600 Rickenbacker Causeway
Miami, FL 33133
tel: 305 361-4851
fax: 305 361-4862
kbroad@rsmas.miami.edu

Mary-Elena Carr
Jet Propulsion Laboratory MS 300-323
4800 Oak Grove Dr.
Pasadena, CA 91101-8099
tel: (818) 354-5097
fax: (818) 393-6720
mec@pacific.jpl.nasa.gov

Dave Checkley, Jr.
Scripps Institution of Oceanography
La Jolla, CA 92093-0218 USA
tel: +01 (858) 534-4228
fax: +01 (858) 822-0562
dcheckley@ucsd.edu

Robert Cowen
Director, Center for Sustainable
Fisheries (CSF)
University of Miami, RSMAS
4600 Rickenbacker Causeway
Miami, FL 33149
tel: 305 361-4023
rcowen@rsmas.miami.edu

Jerome M. Comcowich
IPRC -
International Pacific Research Center
University of Hawaii
2525 Correa Road
Honolulu, HI 96822
comco@soest.hawaii.edu

Jorge Csirke
Chief,
Marine Resources Service (FIRM)
FAO
Vialle delle Terme di Caracalla
00100 Rome, Italy
tel. +39 06 570 56506
fax. +39 06 570 53020
Jorge.Csirke@fao.org

Dave Gilbert
National Institute of Water &
Atmospheric Research Ltd
P.O. Box 14-901
Wellington
New Zealand
Email: d.gilbert@niwa.cri.nz
tel: +64-4-386 0537
fax: +64-4-386 0574
Home telephone: +64-4-568 5360

Michael Glantz
Senior Scientist
ESIG/NCAR
Box 3000
Boulder, CO 80307
glantz@ucar.edu

Safwan Hadi, Dr.
Departemen Geofisika dan Meteorologi
Institut Teknologi Bandung
Jl. Ganesha 10
Bandung 40132
Indonesia
tel: 62-22-250-0409
fax: 62-22-253-4139
e-mail: safwan@geoph.itb.ac.id

Michael Hamnett
Pacific Basin Development Council
Suite 1075
Honolulu, HI 96813-5214
tel: (808) 596-7229
fax: (808) 596-7249
hamnett@hawaii.edu

Toshio Katsukawa
Ocean Research Institute,
University of Tokyo
1-15-1 Minamidai, Nakano-ku,
Tokyo 164-8639, Japan
tel: +81 3 5351 6511
fax: +81 3 5351 6506
katsukawa@0orcu-tokyo.ac.jp

Hak Gyoon Kim
Director,
Marine Environment, Oceanography
& Harmful Algal Bloom Research
Department
National Fisheries Research and
Development Institute (NFRDI)
408-1 Shirang-ri, Kijang-up Kijang-gun,
Busan 619-902, Korea
hgkim@haema.nfrda.re.kr

Jin-Yeong Kim
National Fisheries Research &
Development Institute
408-1, Sirang-Ri
Gijang-Eup
Guang-Gun
Busan 619-902, Korea
tel: (051) 720-2270
fax: (051) 720-2277
jiykim@nfrdi.re.kr

Suam Kim
Dept. of Marine Biology
Pukyong National University
599-1 Daeyeon3 - Dong Nam-Gu
Pusan 608-737, Korea
tel (051) 620-6268
fax (051) 620-6268
suamkim@pknu.ac.kr

R. Michael Laurs
Director, Honolulu Laboratory
Southwest Fisheries Science Center
National Marine Fisheries Service
(NOAA)
2570 Dole Street
Honolulu, HI 96822-2396
tel: 808-983-5300
fax: 808-983-2902
Mike.Laurs@noaa.gov

Patrick Lehodey
Senior Fisheries Scientist
Oceanic Fisheries Programme
Secretariat of the Pacific Community
BP D5
98848, Noumea cedex
New Caledonia
tel: (687) 26 20 00
fax: (687) 26 38 18
patrickl@spc.int
web: http://www.spc.int/oceanfish/

Salvador E. Lluch-Cota
Centro de Investigaciones Biologicas del
Noroeste, S.C.
PO Box 128
La Paz, BCS
Mexico 23000
[Courier delivery:
Centro de Investigaciones Biologicas del
Noroeste, S.C.
Km 0.5 Acceso a la Telefonica s/n
El Conchalito
23096 La Paz, B.C.S. CR-23001
Mexico]
tel: (52-112)53633 ext 3432
fax: (52-112)32756
slluch@cibnor.mx

Hsueh-Jung Lu
Department of Fisheries Science
National Taiwan Ocean University
2, Pei-Ning Road, Keelung, Taiwan
20224, R.O.C.
tel: +886-2-2462-2192 ext.5033
fax: +886-2-2463-2659
hjlu@mail.ntou.edu.tw or
hjlu@ms1.hinet.net

Lorenz Magaard
IPRC -
International Pacific Research Center
University of Hawaii
2525 Correa Road
Honolulu, HI 96822
tel: (808) 956-7509
fax: (808) 956-5035
lorenz@hawaii.edu

Alec MacCall
Fishery Biologist
Santa Cruz Laboratory
National Marine Fisheries Service
110 Shaffer Rd.
Santa Cruz, CA 95060 z
tel: (831) 420-3950
fax: (831) 420-3977
Alec.MacCall@noaa.gov

John Marra
Lamont-Doherty Earth Observatory of
Columbia University
61 Route 9W
Palisades, NY 10964-8000
tel: 1-845-365-8891
fax: 1-845-365-8150
marra@ldeo.columbia.edu

Olivier Maury
IRD
(Institut de Recherche pour le
Développement)
SFA BP 570
Victoria, Iles Seychelles
maury@ird.fr or omaury@sfa.sc
tel & fax: (248) 22 47 42

Jay McCreary
Director, IPRC - International Pacific
Research Center
University of Hawaii
2525 Correa Road
Honolulu, HI 96822
jay@musashimaru.soest.hawaii.edu

Skip McKinnell
Assistant Executive Secretary
North Pacific Marine Science
Organization
c/o Institute of Ocean Sciences
P.O. Box 6000
Sidney, B.C., Canada
V8L 4B2
tel: 1-250-363-6826
fax: 1-250-363-6827
mckinnell@pices.int

Arthur J. Miller
Research Oceanographer
Scripps Institution of Oceanography
Nierenberg Hall, Room 439
University of California, San Diego
La Jolla, CA 92093-0224
tel: (858) 534-8033
fax: (858) 534-8561
ajmiller@ucsd.edu
http://meteora.ucsd.edu/~miller

Raghu Murtugudde
CSS Bldg, Room 2201
Univ of MD, Collge Park, MD 20742
tel: (301) 314-2622
ragu@vinsanto.essic.umd.edu

I-Hsun Ni
Department of Environmental Biology
& Fishery Science
National Taiwan Ocean University
2, Pei-Ning Road, Keelung, Taiwan,
R.O.C.
tel: (886-2) 2463-2341
fax: (886-2) 2462-2192 ext 5013
niih@mail.ntou.edu.tw

Donald Olson
Univ. of Miami, RSMAS
4600 Rickenbacker Cswy.
Miami, FL 33149
tel: 305 361 4074
fax: 305 361- 4696
dolson@rsmas.miami.edu

Robert J. Olson
Inter-American Tropical
Tuna Commission
8604 La Jolla Shores Drive
La Jolla, CA 92037-1508
tel: (858) 546-7160
fax: (858) 546-7133
rolson@iattc.org

Ian Perry
Fisheries & Oceans Canada
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, B.C. V9R 5K6
Canada
tel: (250) 756-7137
fax: (250) 756-7053
perryi@pac.dfo-mpo.gc.ca

Guillermo Podesta
University of Miami, RSMAS
4600 Rickenbacker Causeway
Miami, FL 33149
gpodesta@rsmas.miami.edu

Jeffrey J. Polovina
Honolulu Laboratory
Southwest Fisheries Science Center
National Marine Fisheries Service
(NOAA)
2570 Dole Street
Honolulu, HI 96822-2396
tel: 808-983-5300
fax: 808-983-2902
Jeffrey.Polovina@noaa.gov

Renato Quinones
Department of Oceanography
University of Concepcion
Casilla 160-C, Concepcion
Chile
tel: +56-41-203861
fax: +56-41-256571
rquinone@udec.cl

Ruben Rodriguez-Sanchez
CICIMAR
Apdo. Post. 592
La Paz, B.C.S.
23000, Mexico
street address:
Playa El Conchalito s/n
La Paz, Baja California Sur
23000, Mexico
tels: (52-612) 253-44 / 253-66/ 303-50
fax: (52-612) 253-22
rrodrig@ipn.mx

Claude Roy
IRD (France)
French-South African IDYLE Project
Dept. of Oceanography
University of Cape Town
Rondebosch 7701
South Africa
D6UR9C@mail.uct.ac.za

Rodolfo Serra
Instituto de Fomento Pesquero
Division de Evaluacion de Pesquerias
Casilla 8-V, Valparaiso
Chile
tel: +56-32-212-630
fax: +56-32-213-178
rserra@ifop.cl

Frank Schwing
Pacific Fisheries
Environmental Laboratory
1352 Lighthouse Avenue
Pacific Grove, CA 93950-2097
tel: (831) 648-8515
fax: (831) 648-8440
fschwing@upwell.pfeg.noaa.gov

Eileen Shea
The East-West Center, Burns Hall 2062
University of Hawaii
1601 East-West Road
Honolulu, HI USA 96848-1601
tel: 808-944-7253
fax: 808-944-7376
SheaE@EastWestCenter.org

Jeffrey Shima
Biological Sciences
Victoria University
PO Box 600
Wellington
New Zealand
tel: +64 4 463 6494
fax: +64 4 463 5331
Jeffrey.Shima@vuw.ac.nz

Takashige Sugimoto
Ocean Research Institute,
University of Tokyo
1-15-1 Minamidai, Nakano-ku,
Tokyo 164-8639, Japan
tel: +81 3 5351 6511
fax: +81 3 5351 6506
sugimoto@ori.u-tokyo.ac.jp

Kazuaki Tadokoro
Frontier Research System for
Global Change
31173-25 Showa-machi
Kanazawa-ku, Yokohama-city
Kanagawa 236-0001, Japan
tel: +81-45-778-5602
fax: +81-45-778-5602
denden@jamstec.go.jp

Sandra Tarte
Department of History/Politics
University of the South Pacific
tel: 679 212577
fax: 679 301 487
tarte_S@usp.ac.fj

Simon Thorrold
Biology Department MS # 35
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
tel: 1 508 289-3366 (Office)
1 508 289-2985 (Lab)
fax: 1 508 457-2158
sthorrold@whoi.edu

Sidney Thurston
Associate Program Director,
Austral-Asia Region
NOAA Office of Global Programs
Level 14, Hibiya Central Building
1-2-9 Nishi-Shimbashi Minato-ku
Minato-Ku
Tokyo 105-0003, Japan
tel: 813-5532-7249
fax: 813-5532-7373
Thurston@ogp.noaa.cov

Neil Ward
IRI-The International Research Institute
for Climate Prediction
101 Monell Bldg.
Lamont-Doherty Earth Observatory,
Columbia University
Palisades, NY 10964-8000
tel: (845) 680-4446
fax: (845) 680-4864
nward@iri.ldeo.columbia.edu

Chang Ik Zhang
Permanent address:
Dept. of Marine Production Mgmt.
College of Fisheries Sciences
Pukyong National University
599-1 Diamonding, Nam-go
Pusan 608-737, Korea
tel: (82-51) 620-6124
fax: (82-51) 628-8145
cizhang@dolphin.pknu.ac.kr
Current address:
Visiting Fisheries Scientist
Alaska Fisheries Science Center
NMFS/NOAA
BIN C15700; Bldg. 4
7600 Sand Point Way, NE
Seattle, WA 98115-0070
tel: 206-526-4250
fax: 206-526-6723
Chang.Zhang@noaa.gov

THE INTERNATIONAL RESEARCH INSTITUTE
FOR CLIMATE PREDICTION

LINKING SCIENCE TO SOCIETY

IRI

Climate and Fisheries

INTERACTING PARADIGMS, SCALES, AND POLICY APPROACHES

The IRI-IPRC Pacific Climate-Fisheries Workshop Honolulu, 14-17 November, 2001

Co-organized with
The International Pacific Research Center (IPRC)

SUPPORTING CO-SPONSORS OF THE WORKSHOP:
The North Pacific Marine Science Organization (PICES)
The Center for Sustainable Fisheries (CSF), University of Miami
The GLOBEC International Project Office
The IDYLE Project of the French Institut de Recherche pour le Développement (IRD)

OTHER ORGANIZATIONS PROVIDING SUPPORT FOR ATTENDEES:
The Intergovernmental Oceanographic Commission (IOC)
The Food and Agriculture Organization of the United Nations (FAO)
The NOAA Office of Global Programs
The National Aeronautics and Space Administration (NASA)

COLUMBIA UNIVERSITY

Co-organized with
The International Pacific Research Center (IPRC)

Supporting co-sponsors of the workshop:
The North Pacific Marine Science Organization (PICES)
The Center for Sustainable Fisheries (CSF), University of Miami
The GLOBEC International Project Office
The IDYLE Project of the French Institut de Recherche pour le Développement (IRD)

Other organizations providing support for attendees:
The Intergovernmental Oceanographic Commission (IOC)
The Food and Agriculture Organization of the United Nations (FAO)
The NOAA Office of Global Programs
The National Aeronautics and Space Administration (NASA)

Published by the International Research Institute for Climate Prediction (IRI)
Columbia Earth Institute
Palisades, New York, 10964, USA
IRI Publication IRI-CW/02/1

ISBN 0-9705907-6-8

©2002 International Research Institute for Climate Prediction. All rights reserved.

Climate and Fisheries

INTERACTING PARADIGMS, SCALES, AND POLICY APPROACHES

The IRI-IPRC
Pacific Climate-Fisheries Workshop
Honolulu,
14-17 November, 2001

EDITORS
Andrew Bakun and Kenneth Broad