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An Annotated Bibliography of Climate and Fisheries Interactions

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[redacted]

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CLIMATE AND FISHERIES INTERACTIONS

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INTRODUCTION

Ecologists have for years sought bio-environmental relationships to explain changes in distribution and abundance patterns of marine organisms. Marine ecologists, seeking this information from a biologist's viewpoint (and training), and physical oceanographers seeking it from a physical perspective, focused on living marine resources, and the hybrid science fisheries oceanography was born. These relationships remained elusive generally, and empirical at best, usually due to the lack of a conceptual or causal explanation, or poor and insufficient data. In short, the "signal-to-noise" ratio was poor even when causal relationships were intuitively obvious.

The effects of man's fishing operations on stock, and subsequent recruitment, received a more critical and precise examination, thus yielding useful but inexact information for the resource manager. When predictions failed, the environment was blamed.

Two things happened in 1976 in the United States. First, Federal fisheries oceanographers began to focus their efforts on analyses of time series data of recruitment, catch, Ekman transport, and upwelling (as their ICES European colleagues had for years). Also, conceptual understandings were developed relative to the interactions of first feeding larvae, larval transport, primary production, upwelling, and the overall importance of atmospheric forcing. Second, the passage of the Fisheries Conservation and Management Act of 1976 (FCMA) made it imperative that stock assessments and forecasts, which are the basis for the quotas developed for Optimum Sustained Yield (OSY), be accurate. The worn phrase that the environment was the cause of poor stock-recruitment model output was no longer cogent. These events, linked in time, have precipitated the evolution of many fisheries oceanographers from sea-going data collectors to time series number crunchers. The development of Ekman transport and upwelling indices by National Marine Fisheries Service oceanographers, and their application to recruitment forecasts, have focused the interest and efforts of fisheries biologists and oceanographers on the relationship between interannual variability of selected environmental factors and the resultant interannual fluctuations in recruitment. For an increasing number of stocks under management, the climatological data analyses have helped explain the variability in recruitment.

This latest hybrid of marine scientist, the time series fisheries oceanographer, has been dubbed by one editor as the fisheries climatologist. It is apparent, as one reviews the earlier papers, generally using linear-correlative statistics, and the more recent time series and spectral analyses that single-factor linear relationships only serve to suggest a relationship at best, and at worst, probably the more likely, to mislead. The relationships between an organism and the environmental milieu impacting it consists of many non-linear interactions.

The more successful ventures are with those species that occupy the estuary or near coastal environment during critical life stages.

The more difficult, less definitive are with those living in the buffered open ocean.

The following citations are by no means complete either geographically, species, physical factor or statistically. They are a compilation of historic and current papers that we read, and with our individual bias, decided to include. Criteria for inclusion were generally the conceptual development of a bio-environmental relationship using time-series data. Some concern time series statistical treatments and techniques, or discussions of air-sea interaction.

A common thread which would make Oscar E. Sette smile is the teleconnection between most causal physical oceanographic factors and the atmosphere, particularly for coastal species. A word of advice then to the student biologist, in addition to physical oceanography: you had best take a meteorology course.

Austin, Norcross,
Ingham

ANNOTATED BIBLIOGRAPHY

1. Andrews, J. D. 1969. Climatic and ecological setting for growing shellfish. Proc. Conf. Artificial Propagation of Comm. Valuable Shellfish. Univ. Del., pp. 97-107.

Estuaries exhibit wide ranges of temperature and salinity which require handy species. Oysters exhibit such qualities. West coasts, generally situated in maritime airmasses, and bathed by warm ocean currents, are better, stabler environments than the variable east coasts which oscillate between continental and oceanic air masses. Hardier, resistant east coast species transplant well to the west coasts.

2. Anon. 1977. 1977 white shrimp catch damaged by cold. Fathom Line (SC Sea Grant Publ.), 5(5):2.

Article cites the extreme cold in January and February 1977 as reason for disappearance of the white shrimp. Water temperature dropped to 42°F; critical minimum temperature for white shrimp is 45°F.

Past cold years had good shrimp catches because of migrations from Georgia and Florida. 1977 was so cold that the shrimp were killed there also. (See also Chamberlin, and Armstrong, 1977).

3. Anthony, V. C. and S. Clark. 1979. A description of the northern shrimp fishery and its decline in relation to water temperature. Proc. Climate and Fisheries Workshop, COMS/URI, March 1978. pp. 119-121.

Reviews work by Dow (1963, 1966, see below) and Appollonio and Dunton (1969, see below) and shows that warm winter temperatures (>10°C) in the Gulf of Maine produce poor year classes. Heavy fishing effort on reduced stocks in recent years has masked the climate impacts. Proposes that temperatures >10°C speed egg development with hatching up to one month early. Consequently, larvae are "mis-matched" with spring food supply. Also suggests that a particular egg parasite (protozoan) increases winter mortalities during warmer winters.

4. Appollonio, S. and E. E. Dunton, Jr. MS. 1969. The northern shrimp (Pandalus borealis) in the Gulf of Maine. Job Completion Report, Comm. Fish. Develop Proj. (PL88-309) 3-12-R. 82 pp.

High winter water temperatures appear to adversely affect embryonic development. Collapse of fishery in mid-1950's may have been due to warm temperatures during 1950 to 1953.

5. Armstrong, R. S. 1976. Climatic environmental events related to the fish kill off New Jersey during the summer of 1976. Proc. 1st Ann. Climate Diag. Workshop., Nov. 1976, Wash. D.C. pp. 15.1-15.5.

The 1976 summer New Jersey fish kill was due to low oxygen concentrations below the thermocline. Unusually heavy and early spring river run-off coupled with earlier than normal (February) surface warming produced conditions of summer stratification by spring. Normal late summer O_2 concentrations (<3 ml/l) were reached by early June and anoxia by July. Acceleration towards low O_2 was twice normal, caused in part by an earlier than usual *Ceratium* bloom.

6. Austin, H. M. 1980. Tree rings and mackerel. Coast. Oceanogr. and Clim. 2(2):22-23.

Shows increased Gloucester, Mass., USA Atlantic mackerel landings to be inversely related to growth (tree rings) of Canadian larch (*Larix*) during 1860-1873. Proposes that during cooler years (slow tree growth) mackerel remain in Gloucester fishery later into season.

7. Austin, H. M. 1981. Drought has varied effects on Virginia-North Carolina Fisheries. Coastal Oceanog. and Climatology News, 3(2):17-18.

Drought conditions in the Chesapeake Bay, its tributaries and Pamlico Sound have produced conditions setting up responses by the fisheries. Salinity intrusions upriver have produced favorable conditions for hard clam, oyster and shrimp larvae survival but leave the door open for oyster diseases and predators to move upriver. Several finfish species including bluefish and fluke have been seen further upriver. Freshwater spawning and brackish water nursery grounds for anadromous fish have shrunk to new areas far upriver from normal.

8. Austin, H. and M. Ingham. 1978. Use of environmental data in the prediction of marine fisheries abundance. Proc. Climate & Fisheries Workshop, March, 1978; Alton Jones Campus, U.R.I. pp. 5.1-5.6.

Authors propose criteria for selection of species and physical data bases to model for climate variability and concomitant fishery fluctuations. Cite several "classical" fishery oceanography papers and provide annotated bibliography.

9. Bakun, A. 1979. Coastal meteorological data needs for fisheries management. Expanded abstract. Workshop on Environmental Data in Coastal Regions, AMS, Boston, November 5-7, 1979. 8 pp.

Review paper on the importance of coastal wind patterns to Ekman transport upwellings, larval transport, and recruitment success or failure. Wind also produces turbulent mixing which destroys fine-scale forage patches. Cites examples of several papers abstracted herein (Lasker; Nelson, Ingham and Schaaf; Peterson; Parrish and MacCall; Hayman).

10. Bakun, A., C. S. Nelson and R. H. Parrish. 1979. Determination of surface drift patterns affecting fish stocks in the California Current Upwelling Region. Seminar/Workshop on Ocean Products by IGOSS, Moscow, 2-11 April 1979. IOC/WMO, 15 pp.

In the Pacific Northwest coastal fish with pelagic larvae spawn during winter when surface wind-drift is generally onshore, and not during more productive upwelling season, but with offshore transport. In the upwelling region of N. California where upwelling is all year, and transport offshore, there is little local spawning. Most fishery species migrating from the Southern California Bight were the spawn under "closed gyre circulation patterns."

This produces distinct faunal assemblages. "The apparent dependence of spawning strategies upon surface drift conditions suggests the hypothesis that anomalies in surface drift patterns could be a cause of the observed wide variations in spawning success of the major fishery species of the California Current region." (Similar to Parrish, Nelson and Bakun, 1981.)

11. Bakun, A. and R. H. Parrish. 1981. Environmental inputs to fishery population models for eastern boundary currents regions. In Effects of Environmental Variation on the Survival of Larval Marine Fishes. (G. D. Sharp ed.). Workshop Report 28, Intergovt. Oceanogr. Comm. UNESCO, Paris, pp. 1-37.

Paper reviews pertinent literature relative to environmental effects on larval survival in the California, Peru, Canary and Benguela Current systems. It suggests that while empirical models, based on studies, cannot be expected to provide reliable predictions, they can provide an indication of tendencies created by environmental variability.

12. Bannister, R., D. Harding and S. Lockwood. 1974. Larval mortality and subsequent year class strength in the Plaice. J. H. Blaxter (ed.) The Early Life History of Fish. Springer-Verlag, New York, pp. 21-38.

The winter of 1974 was very cold with extensive 0° water which should have altered recruitment, yet the (1973?) year class was highest on record. Suggests that the cycle was delayed so more advanced larvae were present.

13. Bardach, J. E. and R. M. Santerre. 1980. Climate and Aquatic Food Production. East-West Res. Sys. Inst., E-W. Center, Univ. of Hawaii, WP-80-11. 47 pp.

Essentially an elongated form of Bardach and Santerre (1981) [see below] but includes references on aquaculture. Suggests that aquaculture is less influenced by climate fluctuations than are natural systems.

14. Bardach, J. E. and R. M. Santerre. 1981. Climate and the fish in sea. Bio Science. 13(3):206-214.

Paper is a review of previous review papers (e.g. Cushing and Dickson, 1976; NMFS-EDS Climate and Fisheries Workshop Proceedings). Cites most important effect of climate on aquatic production as variations in temperature.

15. Bell, F. and A. Pruter. 1958. Climatic temperature changes and commercial yields of some Marine Fisheries. J. Fish. Res. Bd. Canada. 15(4):625-683

Most (as of 1958) climate temperature - fish productivity (landings) relationships do not give sufficient provision for changes in fishing effort to explain climate - fish relationships. (ed. note - Most relationships examined here were air temperature).

"The effects of other variables such as economic conditions, changes in fishing practices and the extent of the removals by man should be accounted for. The possibility of fortuitous relationships must be discounted by exhaustive tests of the representativeness and adequacy of the environmental data, and equal care must be exercised in the selection and evaluation of the fishery data, particularly that of catch per unit effort."

16. Bjerknes, J. 1969. Atmospheric teleconnections from the equatorial Pacific. NOAA Weather Rev. 97(3):163-172.

A trough over the eastern U.S. in 1958-59 resulted in the coldest winter to that date since 1917-18, and a similar pattern in the 700 mb level in 1939-40 produced a cold wave that year. The 1948-49 winter was warm with a reverse pattern at 700 mb (ridge over eastern U.S.). When low temperature anomalies are present off east coast (e.g. 1958) then positive anomalies are found off California.

Several El Nino relationships are also discussed, as tabulated below.

El Nino Years	Non El Nino Years
1. 1972 SST up 5°C	Average SST
2. High heat supply in equatorial Pac.	Normal
3. Intensified Hadley circulation	Normal circulation
4. Increased flux of angular momentum	Normal
5. Intensified wind-latitude westerlies	Normal

17. Blackburn, M. 1969. Conditions related to upwelling which determine distribution of tropical tunas off western Baja California. Fish. Bull. 68(1):147-176.

Tuna were found to aggregate only where and when when pelagic red crabs Pleuroncodes planipes were found. P. planipes are an index of abundant food. Tuna did not aggregate even when temperatures were suitable unless the crab did. Aggregate behavior of the crabs was produced by upwelling in waters of high chlorophyll content.

18. Carruthers, J. N. 1938. Fluctuation in the herring of the East Anglian autumn fishery, the yield of the Ostend spent herring fishery, and the haddock of the North Sea- in the light of relevant wind conditions. Rapp. P.-v. Réun. Cons. perm. int. Explor. 107(3):10-15.

Links wind conditions off England with fish catch. When winds are from the Channel, herring spawning products drift to favorable environment and later become available to the Ostend fishery. Graphs show cross correlations between pressure gradient and herring data.

Herring and haddock stocks fluctuate inversely. Influence of wind on surface oceanic transport is great enough to cause fluctuations in year-class strength, as evidenced by 1923 and 1928 peak catches and 1922 and 1927 poor haddock years.

19. Carruthers, J. N. 1951. An attitude on "fishery hydrography." J. Mar. Res. 10(1):101-118.

Makes a general case for inexpensive monitoring of meteorological parameters in the study of long-term linkages between year-class strength or catch and environmental variations. Relates good correlations between computed winds and year-class strengths of haddock, herring, cod and hake in the northern North Sea.

20. Cayan, D. R. 1980. Regimes and Events in Recent Climate variables. CalCOFI Rep. Vol. XXI:90-101.

Extreme environmental events often show a relation to long term regimes. Autocorrelations of lower atmospheric and sea surface temperatures suggest the ocean acts as a stabilizing agent on the atmosphere, and hence SST's are examined as short term climate predictions. Although cause and effects are incompletely understood there is a clear and strong coherence between ocean temperature anomalies and their atmospheric counterparts.

21. Chadwick, H. K. 1967. Recent migrations of Sacramento - San Joaquin River striped bass populations. Trans. Amer. Fish. Soc. 96(3):327-342.

Striped bass coastal migrations are only found during "warmer" years. During "normal" or "colder" years the San Joaquin/Sacramento stock remains in the Bay. Extensive migrations were undertaken during late 1950's warming.

22. Chamberlin, J. L. and R. S. Armstrong. 1977. Data on cold weather conditions along the Atlantic and Gulf coasts during the fall and winter of 1976-1977. NMFS Mar. Environ. Notice. 9 pp.

Cold conditions during fall and winter of 1976-1977 were more severe, persistent, and widespread along the Atlantic Coast than in the previous 40 years. Mortalities of snook (Florida), white shrimp (S. Carolina), and croaker (Va.) were reported. (See also Anon. 1977.)

23. Chase, J. 1955. Winds and temperatures in relation to the brood strength of Georges Bank haddock. J. Cons. Perm. int. Explor. Mer, 21(17-24).

Relates losses in year classes of haddock on Georges Bank to northwest winds, as derived from pressure measurements, during the pelagic season of the larvae. Correlations were improved (to $r^2 = .766$) by estimating spawning time from air temperature changes. Suggested need for better understanding of relationships before correlations could be improved.

24. Clark, N., T. Blasing and H. Fritts. 1975. Influence of interannual climatic fluctuations on biological systems. Nature, Vol. 256:302-305.

Growth of conifers in western North America and the distribution of albacore tuna along the west coast of N. America are linked by large scale atmospheric flow patterns which are influenced by air-sea interaction processes over the eastern N. Pacific.

25. Cohen, T. J. and Sweetser, E. J. 1975. The "spectra" of the solar cycle and of data for Atlantic tropical cyclones. Nature, Vol. 256:295-296.

A relationship exists between the solar cycle (sun spots) and the occurrence of Atlantic tropical cyclones. Prominent spectral components were located at 15 and 22 years for the length of the cyclone season but only weakly so for sun spot numbers. Smoothed number of N. Atlantic cyclones, smooth length of season and running mean sun spot numbers did suggest a relationship. No explanation is offered.

26. Colebrook, J. M. 1979. Continuous plankton records: seasonal cycles of phytoplankton and copepods in the North Atlantic Ocean and North Sea. Marine Biology, Vol. 51, pp. 23-32.

Analysis of data and continuous plankton recorder surveys in the North Atlantic Ocean and North Sea were used to study geographical variations in amplitude duration and timing of seasonal cycles of total phytoplankton and total copepods. They demonstrate a relationship between the timing of the spring increase of phytoplankton and the amplitude of the seasonal variation and sea surface temperatures. Comparisons are made between long term trends in the North Sea and open North Atlantic Ocean. Spring increases were found to occur in the North Sea associated perhaps with transient periods of vertical stability which often resulted in a slower rate of phytoplankton increase. Discussion is related back to Craig (1960) in which he shows the timing of the spring increase is in part related to development of stability of the surface waters.

The timing of phytoplankton increase is shown to be correlated with seasonal range of temperatures and is interpreted

as an indicator of vertical stability. The adverse of vertical stability is mixing. It seems "reasonable to expect winter survival to be influenced by vertical mixing processes through losses to deep water."

27. Colton, J. B. and R. F. Temple. 1961. The enigma of Georges Bank spawning. Limnol. and Oceanogr., Vol. 6. pp. 280-291.

General circulation pattern on Georges Bank is northeast into slope waters and hence to Gulf Stream. Pattern is such that haddock and herring should be lost. Normal winds exacerbate situation. Year class strength is maintained by high fecundity and stock size (pre 1960's). Exceptional wind/current conditions can produce large year-classes.

28. Colton, J. B., Jr. 1972. Temperature trends and the distribution of groundfish in continental shelf waters, Nova Scotia to Long Island. Fish. Bull. 70(3):637-657.

Studies the distributional changes in 4 species (American plaice, haddock, yellowtail flounder and butterfish) of groundfish during a period of changing water temperature 1950-68.
Found some response in 2 species, plaice and butterfish during a cooling period, but it wasn't extensive and significant.

29. Craig, R. E. 1960. A note on the dependence of catches on temperature and wind in the Buchan pre-spawning herring fishery. J. Cons. Perm. int. Explor. Mer, 25(2):185-190.

Summarizes work of others on effects of temperature and wind on herring four years old and older in the Buchan pre-spawning

fishery (negative). The availability of herring in the fishery is related to both wind and spring rate of change of temperature 1930-1949. Relationships were less clear thereafter (1950-1957).

The relationship is assumed to be related to changes in behavior, distribution or aggregation.

30. Cushing, D. H. 1972. The production cycle and numbers of marine fish. Symp. Zool. Soc., London. 29:213-232.

The 1963 year class of plaice was excellent following a cold winter which delayed both larval metamorphosis and the spring bloom. The bloom, once it occurred, was intense and matched with the peak of larval abundance, hence good survival.

31. Cushing, D. H. 1975. Marine Ecology and Fisheries. Cambridge Univ. Press, Cambridge and New York. 278 pp.

Book provides basic discussion on oceanic production cycles, food webs, and migration as they vary temporally with a fluctuating environment. Chapter 11 (Climatic changes in life in the sea) documents dependency of recruitment fluctuations on interannual physical environmental variability.

32. Cushing, D. H. 1976. The impact of climate change on fish stocks in the North Atlantic. Geographical J. Vol. 142. pp. 216-227.

Discusses hemispheric warming (1920's-1945) and cooling (1945-present) trends and cites rise and fall of West Greenland cod fishery as example with causative factors explained. Refers to the "Russell Cycle" (1930-40 warming) and discusses periodic (1925-1972) fluctuations at ocean station E1 as demonstrating warm

water features monitored during 1930-1965. Presents several examples of match-mismatch of larval herring abundances and forage due to wind patterns.

33. Cushing, D. H. 1978. Biological effects of climate change. Rapp. P.-v. Réun. Cons. int. Explor. Mer, 173:107-116.

Notes "fuzzy" periodicities in several geographically disparate fish stocks and suggests environmental forcing is probably somehow teleconnected.

N. Hemisphere warming (+0.5°C) 1880-1945 resulted in northward extensions by many species (cod off Greenland). General cooling since 1945-50, now boreal species, moving south.

Development rates of egg/larvae are a power function of temperature. Chance of forage match is increased with lower temperatures which "spreads" larvae through time. Year-class strength inverse to temperature.

34. Cushing, D. H. and R. R. Dickson. 1976. The biological response in the sea to climatic changes. <u>In</u> Russell and Young (eds.) Advances in Marine Biology, Vol. 14. Academic Press. pp. 1-121.

Magnitude of herring recruitment is directly correlated with quantity of winter phosphorus one year after hatching, and number of pilchard eggs is inversely correlated with winter PO4 6 months after hatching.

Fish near northern or southern end of range show greater response to climate variation than do those in center. Clupeid and salmonids react quickly whereas gadoids don't. Perhaps due to fecundity - more fecund species tend towards stabilization.

Fish with fixed spawning cycles (generally North of 40°N) are more susceptible than those south of 40° where productivity continues all year.

Spring bloom often occurs at the same time each year, but spring spawning can vary. Match or mis-match is important as cold water often delays larval abundance - spring bloom is more photoperiod dependent until productivity is high. Russell cycle during early 1930-40's general warming, most profound in 1926-35. Reversed from 66 to 72 by general cooling. Named after Russell, its "discoverer." Ecosystem response is step-like with sudden changes at beginning and end of cycle.

35. Dahlberg, M. D. 1979. A review of survival rates of fish eggs and larvae in relation to impact assessments. Mar. Fish. Rev., March 1979. pp. 1-12.

Environmental conditions must be known between areas before their fish stocks can be compared. Author reviews past work (e.g. Bannister, et al. 1974). The works that report low temperatures prolong larval development time and hence prolongs exposure to predation.

Storms and wave action cause mortality by stranding demersal eggs on beaches.

Environmental conditions during prolonged postlarval development may be more important than during egg and yolk-sac environment.

36. Dall, W. 1980. Northern prawn fisherman pray for rain. Australian Fisheries, Dec. 1980 pp. 3-4.

High rainfall during the wet season ($\geq$ 40 inches) results in better recruitment of banana prawns. Year-to-year variations in landings are attributed to year-to-year differences in rainfall.

37. Dow, R. L. 1964. A comparison among selected species of an association between seawater temperature and relative abundance. Extr. J. Cons. int. Explor. Mer, 28:425-431.

    Compares Maine landings of lobster, scallop and shrimp with annual average water temperature at Boothbay Harbor, temperature/biota cycles were lagged until a fit was found. No statistical treatment of data.

38. Dow, R. L. 1969. Cyclic and geographic trends in seawater temperature and abundance of American lobster. Science (146):1060-1063.

    Fluctuations in abundance of American lobster and seawater temperature have correlated well during period 1905-present. Optimum center of catch moving southward as temperatures drop.

39. Dow, R. L. 1977. Effects of climatic cycles on the relative abundance and availability of commercial marine and estuarine species. J. Cons. Perm. int. Explor. Mer, 37(3):274-280.

    Correlated annual average sea surface temperatures at Boothbay Harbor with Maine landing data for 1905-1967. Total number of species in Gulf of Maine increased during period of warming. Individual species catch correlation coefficients ranged from $r^2 = 0.86$ for lobster to $r^2 = 0.91$ for scallop (1939-67).

Total catch vs. temperature yields a coefficient of $r^2 = 0.63$ for the same period.

40. Evans, R. H., D. R. McLain and R. A. Bauer. 1979. Atlantic skipjack tuna: influence of the environment on their vulnerability to surface gear. Southwest Fish. Ctr. Admin. Rep. No. LJ-79-38, 12 pp, 9 figs.

The depth of the 3.5 ml/l D.O. surface and 18° isotherm in combination provide a viable constraint on the skipjack habitat. This means that:

1. All the Atlantic Ocean between 40°N and 40°S are a suitable skipjack habitat;
2. The habitat depth is shallowest in the eastern Atlantic becoming deeper to the west, and deepest at the center of the subtropical gyres;
3. Coastal upwelling, in addition to increasing primary production, causes the 3.5 ml/l floor to shoal; and
4. Advection and turbulent mixing may displace the "floor" away from the upwelling area.

Skipjack are only vulnerable to surface gear in the upper 50 m. From this only the following areas are "fishable".

1. Nearshore, east coast S. America 16-32°S,
2. Coastal Brazil and Venezuela 48°W-68°W, and
3. Northern edge of Gulf Stream off U.S. north of 35°N.

Purse seine gear is hampered by winds in excess of 8 m/sec (16 kts.). These areas are generally in the equatorial regions.

41. Fable, W. A., H. A. Brusher, L. Trent, and J. Finnegan. 1981. Possible temperature effects on charter boat catches of King Mackerel and other coastal pelagic species in Northwest Florida. Mar. Fish. Rev. 43(8):21-26.

Dramatic changes in charter boat landings, species composition, and size of fishes caught during the summers of 1977 and 1978 led to investigations as to the cause(s) of the sudden changes. Analysis of data from 1965-78 showed that catch per hour (CPH) was related to temperatures the previous winter. High CPH was associated with high winter temperatures, and low CPH with low temperatures.

42. Farlow, S. J. 1981. The GMDH (Group Method of Data Handling) algorithm of Ivakhnenko. Amer. Statistician 35(4):210-215.

The GMDH is a statistical technique for constructing very high-order regression type polynomials. It is described as ideal for large complex and unstructured data sets; particularly those for which no "preconceived ideas" (conceptual model or hypothesis - ed note) exist. The method is heuristic (instructive) in that it suggests the structure extant in the data set. Examples of uses given include long-range prediction of river run off, dynamics of plankton ecological systems, and wheat growth predictions in terms of several climatic factors. (See also paper by Kishi, M. J.)

43. Favorite, F. and W. J. Ingraham. 1976. Sunspot activity and ocean conditions in the Northern North Pacific Ocean. J. Oceanogr. Soc. Japan. (32):107-115.

Sunspot maxima (every 11 years) move means winter position of Aleutian Low from Gulf of Alaska to western Aleutians. Wind-stress transport is reduced by 20% in the Gulf of Alaska. Increase in solar constant during rising phase and declining phase. 5-6 year period. SST anomalies also 5-6 year period. These temp. peaks correspond with dominant year classes of:

Pacific Herring 1953, 1958

Dungeness crab 1963, 1964, 1968

Sockeye salmon 1952, 1956, 1961, 1965, 1970

(ed. note: 11 year cycle also noted by Southward, et. al. 1975 in Gulf of Maine, 6 year by Lyman 1974 for striped bass.)

44. Flowers, J. M. and S. B. Saila. 1972. An analysis of temperature effects on the inshore lobster fishery. J. Fish. Res. Bd. Canada. 29:1221-1225.

Correlates water temperatures at Boothbay Harbor, St. Andrews and Lurcher Shoals Lightship with lobster catches 1970) pooled for 6, 7 and 8 years (r^2 = .87). Using bottom temperature from lightship improved correlations (r^2 = .94).

45. Frank, K. T. and W. C. Leggett. 1981. Wind regulation of emergence times and early larval survival in capelin (Mallotus villosus). Can. J. Fish Aquat. Sci., 38:215-223.

Emergence and survival of larval capelin from beach gravel nests are correlated with onshore wind-induced wave action. Increased emergence and survival are dependent upon frequent events. The longer the period between events the more larvae and the poorer their condition in gravel.

46. Garcia, C. 1976. Utilization of the prediction of temperature by the fisheries operations on the Northern Campeche Banks. Rev. Invest. INP, 2(2):126-132. (In Spanish)

Details plans to work with the Meteorological Institute to develop synoptic charts and predict bottom water temperatures in the Gulf of Mexico. Changes in bottom temperatures have been directly correlated with movement of red grouper Epinephelus morio. Prediction of bottom temperatures would allow the fishing fleet advance knowledge of fish location and movement. The ultimate goal is to get the information in the hands of the fishing fleet.

47. Garrod, D. J. and J. M. Colebrook. 1979. Biological effects of variability in the North Atlantic Ocean. Rapp. P.-v. Réun. Cons. int. Explor. Mer, 173:128-144.

Clearest impact of environmental forcing on marine animals is in seasonal fluctuations of primary productivity. Interannual variations in recruitment are probably due to environmental fluctuations and parent stock size.

Time series analyses of Arctic cod and N. Sea plaice show coherence with atmospheric pressure patterns. Also herring recruitment (in time series) show relationship to zooplankton variations.

48. Gaskell, T. F. 1979. Climate variability, marine resources and offshore development. Proc. World Climate Conf., Geneva 12-13 Feb. 1979. WMO No. 537 pp. 634-651.

Discussion on the importance of climate and weather forecasting to the offshore oil industry. Relates weather's importance to oil spill slicks, ship routing, and offshore operational decisions. Says oil is the most important marine resource.

49. Glover, R. S., G. A. Robinson and J. M. Colebrook. 1974. Marine biological surveillance. Environment and Change. Feb.:395-402.

- Time series w/CPR (Hardy) 1948-1972 shows the following.

1. Total number of copepods has decreased
2. Duration of abundance has decreased from 7.25 to 6.0 mo.
3. Atlantic Ocean waters have extended further north since WWII, however reversal in recent years.

"...flippant to relate the plankton trends to the illegitimacy rate in teenage girls..." In other words, don't use single environmental parameters.

50. Glynn, P. W. 1979. Climatic cycles may affect reef growth. Smithsonian Res. Rept. Autumn, 1979. p. 4.

The extensive coral reefs off Costa Rica were killed during the last ice age; and periodic upwelling episodes, while enhancing productivity, produce waters below the thermal minimum for coral growth. Consequently Costa Rican coral reefs are "stunted."

51. Gulland, J. A. 1952. Correlations on fisheries hydrography. Letters to the editor. J. Cons. Perm. int. Explor. Mer, 18:351-353.

Criticizes methods used by Carruthers (1951) in selecting wind data by month (variable) and direction to improve correlations between year-class strength and wind. Demonstrates a good correlation between random numbers using similar techniques.

52. Gulland, J. A. 1965. Survival of the youngest stages of fish and its relation to yearclass strength. ICNAF Spec. Publ. 6:363-371.

Author discusses relationships between fecundity and mortality with mortality rates of egg-larvae being a major cause of good and bad yearclasses. Yearclass fluctuations, while possibly keyed to an environmental factor(s) is hard to estimate as statistical correlation techniques are insufficent in view of the wide range of environmental factors and interactions. Even environmental factors demonstrating a direct impact are hard to prove due to difficulties in estimating recruitment and environmental factors.

53. Gulland, J. A. 1978. Problems and progress in oceanography relevant to fisheries. FAO Fisheries Rept. 206, Supplement. 1. Rept. of 9th Session of ACMRR, Rome. pp. 9-14.

In studying effects of environmental fluctuations on fisheries, and particularly for forecasting, two considerations must be made:

1. which parameters affect the stocks, and how; and

2. understand the climatic fluctuation of the parameter, and hence its use in forecasting.

Understanding distribution patterns of fish stocks relative to oceanographic features, and the distribution of the feature in time and space make locating areas of "high vulnerability" easier and more cost effective.

Recruitment (year-class strength) forecasts are most valuable for forecasts, but will not be a practical reality until we have "...a better understanding of the process determining year class strength."

54. Gunter, G. and J. C. Edwards. 1967. The relation of rainfall and freshwater drainage to the production of the Penaeid shrimps (*Penaeus anviatilis* and *P. aztecus*) in Texas and Louisiana waters. Proc. World Sci. Conf. on Biol. and Culture of Shrimps and Prawns. FAO Fish Repts. 57(3):875-892.

High positive correlation between white shrimp landings and rainfall in Texas that year, and the two previous years. Brown shrimp show no correlation.

55. Hartline, B. K. 1980. Coastal upwelling: Physical factors feed fish. Science 208:38-40.

Article describes CUEA (Coastal Upwelling Ecosystems Analysis) "physical and biological processes are in a sequence, so understanding the ecosystem requires understanding the sequence. A [marine] biologist out there with no understanding of meteorology or currents is just whistling in the dark."

Article discusses local winds, nearshore currents, and waves spawned by remote processes as all influencing the productivity of prime coastal fishing grounds.

56. Hassler, W. W., N. L. Hill, J. T. Brown. 1981. The status and abundance of striped bass, *Morone saxatilis* in the Roanoke River and Albermarle Sound, North Carolina, 1956-1980. Spec. Sci. Report No. 38, N.C. Dept. Nat. Res. and Comm. Devel., 156 pp.

Year to year fluctuations in abundance of young of the year and dominant yearclasses are not dependent upon the severity of the preceding winter as found for Chesapeake Bay stocks (Kohlenstein, 1980). Low to moderate river flow was found to favor abundance and growth. High flows were unfavorable.

57. Hayes, R. M., D. G. Mountain and T. C. Wolford. 1977. Physical oceanography and the abiotic influence on cod recruitment in the Flemish Cap region. ICNAF Research Document 77/VI/54 (Revised).

Develops multiple linear regression model relating total population of 4-yr. old cod 4 years hence to mean April sea temperatures, meridional Ekman transport, zonal Ekman transport and total population (spawners) on Flemish Cap. Covered 1955-63 in physical data and 1959-67 in model output (4-yr cod population - correlation coefficient of 0.91 - conceptual model not clearly described.

58. Hayman, R. A. 1977. The relationship between environmental fluctuation and year-class strength of Dover sole (*Microstomus pacificus*) and English sole (*Parophrys vetulus*) in the fishery off

the Columbia River. Master's Thesis, Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon.

Models correlating environmental variables to Dover sole (*Microstomus pacificus*) and English sole (*Parophrys vetulus*) year-class strength were developed. Variables considered were temperature, sea level, barometric pressure, indices of offshore and alongshore transport, offshore divergence indices, wind speed, solar radiation, and Columbia River discharge and water quality. In addition to monthly mean values of these factors, the models also considered shorter term measures of environmental variability, such as number of wind direction shifts, storm frequency and duration, and factors that measure variability when combined as separate terms in a multiple regression, for example storm frequency plus wind speed. These short-term variability measurements may reflect production cycles more closely than monthly mean figures. Also considered in the models was spawning power, calculated as egg production summed for each length group.

59. Hayman, R. A. and A. V. Tyler. 1980. Environment and cohort strength of Dover sole and English sole. Trans. Am. Fish. Soc. 109:54-70.

A correlation model incorporating two oceanographic factors, upwelling in early summer and offshore divergence the next summer, explained 65% of the cohort strength variation in Dover sole (*Microstomus pacificus*) off the Columbia River. Upwelling influenced food availability following yolk sac absorption; and winter convergence, which sets up fronts that would act to prevent inshore transport of larvae at time of settling, was also associated with large cohorts of Dover sole. The cohort strength in English sole was related to sea surface temperature, upwelling, and barometric pressure in the early fall, prior to spawning. This suggests that spawning was delayed in English sole if upwelling was prolonged in the fall because bottom temperatures are positively related to cohort strength and delayed spawning was linked to stronger cohorts.

60. Heinle, D. R., D. A. Flemer and J. F. Ustach. 1977. Contribution of tidal marshlands to mid-Atlantic estuarine food chains. Pages 309-320 in M. L. Wiley (ed.), Estuarine Processes. Circulation, sediments and transfer of materials in the estuary. Academic Press, N.Y.

Seasonal pulses of carbon flow from tidal marshes results in pulsed zooplankton production for detritivores. Interannual variations in detrital pulses result in fluctuations in zooplankton abundance which appear to be an important regulating factor in larval fish survival.

61. Hempel, G. 1978. North Sea fisheries and fish stocks, a review of recent changes. Rapp. P.-v. Réun. Cons. int. Explor. Mer, 173:145-167.

Single stock management concept becoming outdated. Must consider complex physical environmental and prey/predator relationships. Paper reviews changes in stocks of North Sea mackerel, haddock, cod, whiting, plaice, and sole and relates them to atmospheric climatic fluctuations. Atmospheric circulation over the N. Atlantic has changed since 1920's. Since 1940's westerly flow has weakened and North/South amplitude of waves has

increased. While conceptual link has not been forged, several possibilities exist:

1. Vertical mixing- hence depth of mixed layer changes.
2. Temperature regimes have changed, but not always uniformly with atmospheric changes, and no long term trends are pronounced.

62. Hunt, J. H., R. J. Carroll, V. Chincilli and D. Frankenberg. 1980. Relationship between environmental factors and brown shrimp production in Pamlico Sound. N.C. Spec. Sci. Rept. No. 33. NCDNR&CD. 29 pp.

A model predicting brown shrimp (Penaeus aztecus) harvest in Pamlico Sound is developed using April-May temperatures and salinities. Growth rates decrease and mortality rates increase when spring salinities are below 10 $^{o}/_{oo}$ and temperature below 20°C.

63. Hurt, P., L. Marshall-Libby, L. Pandolfi, L. Levine, and W. Van Engel. 1979. Periodicities in blue crab population of Chesapeake Bay. Climate Change, Vol. 2.

Analysis of blue crab catch in the Chesapeake Bay from 1922 to 1976 show variations with periods of 18.0, 10.7, 8.6 years. These variations are found to be related to a 9.8 and 10.7 period for temperature and the 18.0, 8.6 and 7.4 year periods agree with the Earth-Moon-Sun tidal period. The temperature may be related to the 10.5 year sun spot cycle.

64. Iles, T. D. 1973. Interaction of environment and parent stock size in determining recruitment in the Pacific sardine as revealed by

analyses of density dependent O-group growth. Pages 228-240 in B. B. Parish (ed.) Fish Stocks and Recruitment Symposium. Rapp. P-v. Reun. Cons. Perm. Int. Explor. Mer. 164:372 pp.

Abundance and O-group growth data on Pacific sardines for 1933-55 suggested that low survival indices which could not be explained by biological data must be due to environmental influences. Similar effects simultaneously in Canadian herring, salmon and lake fish suggests broad-scale weather effects possibly responsible. Used no environmental data in study.

65. International Oceanographic Commission. 1980. Workshop on the Effects of Environmental Variation on the Survival of Larval Pelagic Fishes. Sharp, G. Rapporture OIC Workshop Rept. No. 28, Lima, Peru, 323 pp.

Workshop focuses on Peruvian anchovy and other eastern boundary current stocks with emphasis on early life stages and environmental, stock size, and interspecies interactions.

66. Iselin, C. O. D. 1955. Coastal currents and the fisheries. Deep Sea Res. Suppl. 3:474-478.

Discusses coastal circulation patterns and their impacts upon fisheries. Physical processes appear to be important factors governing fluctuations in annual recruitment of young fish. Large scale processes are involved insofar as they affect the physical environment. Fish can deal with "normal" changes but not physical "catastrophes."

The coastal environment is characterized by the physical oceanographer to help the fishery biologist:

1. Quantitative changes in land drainage affect the coastal marine environment.
2. There are significant physical differences between coastal and offshore waters.
3. Abnormalities of weather manifested in wind pattern/ strength changes.

Iselin calls for continuous physical observations (monitoring) to evaluate biological fluctuations.

67. Jeffries, H. P. and W. C. Johnson. 1973. Seasonal distribution of bottom fishes in the Narragansett Bay area: Seven-year variation in the abundance of winter flounder (Pseudopleuronectes americanus). J. Fish. Res. Bd. Canada 31(6):1057-1066.

Slight increases in April temperatures (<1-0°C) over a seven year period are felt to be the causative factor (75% of variation) resulting in a decline in the winter flounder population, the chief effect being a hastening of larval metamorphosis. They also found that juvenile surveys can be used to "forecast" commercial catch 2-3 years later.

68. Johnson, J. H. 1961. Sea temperature and the availability of albacore (Thunnus germo) off the coasts of Oregon and Washington. U.S. Bur. Comm. Fish. Paper No. V-6.

Fluctuations in the albacore fishery off Oregon and Washington are the result of yearly variations in abundance and variations in availability, not of fishing effort.

Movements of albacore of the North American coast have been associated with northward movement of the 59°F isotherm. Landings are down in years of "cold" waters.

If the sea temperature anomaly is large enough, it is possible, in June, to predict if there will be favorable conditions for albacore starting in mid-July.

69. Johnson, J. H. 1976. Food production from the oceans: historical, present, and potential harvest of ocean food resources. Proc. NMFS/EDS Workshop on Climate and Fisheries. Col., Mo. pp. 15-36.

General discussion on historical and proposed potential oceanic harvests. Climatic impacts on global marine production not statistically discernible. Discusses species/stock specific examples of climatic variability and resultant fluctuations in fisheries. Ties several globally telecommunicated events together such as El Nino/Southern Oscillation Index to U.S. Soybean/Menhaden meal prices.

70. Johnson, J. and D. McLain. 1975. Teleconnections between north-eastern Pacific Ocean and the Gulf of Mexico and northwestern Atlantic Ocean. Fish. Bull. 73(2):306-316.

Air/sea interactions in Pacific influence topography of 700 mb circulation patterns, which in turn, as the steering currents, result in blocking (ridge) cold continental air masses or their passage (trough) far to the south. Hence SST anomalies along the eastern U. S. seaboard are influenced by them.

71. Johnson, J. H. and G. R. Seckel. 1977. Use of marine meteor-ological observations in fisheries research and management. Environmental Data Service NOAA Sept. 1977, U. S. Dept. of Commerce. p 3-12.

Gives examples of relationships between fisheries and climate: Bering Sea salmon and cold weather in 1970's, Atlantic menhaden and Ekman transport, Pacific mackerel and upwelling, dungeness crab and upwelling, skipjack migrations and barodinic currents, anchoveta and El Nino and atmospheric pressure fields. Points out empirical nature of most fishery climate studies.

72. Ketchen, K. S. 1956. Factors influencing the survival of the lemon sole (Parophrys vetulus) in Hecate Strait, British Columbia. J. Fish. Res. Bd. Canada. 13(5):647-694.

Develops a conceptual model linking lower water temperatures with stronger year classes, with correlation coefficients ranging from -0.696 to -0.904, depending on period assumed for peak spawning, lower temperatures favor slower larval development and longer pelagic drift, allowing larvae to reach favorable nursery area before settling to bottom. In warm years the larvae apparently fall short and perish.

73. Kishi, M. J. 1981. [English Abstract] Prediction of the catch at the set net using the GMDH (Group Method of Data Handling), - Prediction of the catch of jack mackerel at Komekaini set net using sea surface temperatures. Bull. Jap. Soc. Fisheries Oceanog. No. 38, pp 1-5.

Daily catch of jack mackerel are predicted from a polynominal of catch and sea surface temperatures from several locations.

74. Kohlenstein, L. C. 1980. Aspects of the population dynamics of striped bass (Morone saxatilis) spawning in Maryland tributaries

of the Chesapeake Bay. Ph.D. Dissertation, Johns Hopkins Univ., JHU/PPSE T-14.

Develops stock-recruitments (Ricker curves) modifying them to include "density-independent" environmental variables. Cites previous work (Heinle, 1977) and uses time series of winter air temperature anomalies and spring (April-May) runoff in Potomac River as environmental forcing factors. Model accounts for up to 80% of interannual recruitment fluctuations with environmental variables.

75. 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(3):453-462.

Study showed how laboratory-spawned larvae can be used to detect larval feeding grounds at sea. Author suggests may be used to provide link between marine food chain research and stock and recruitment predictions in fisheries.

Variations in year-class strength may be dependent upon larval first feeding survival rather than spawning population size. Density of food organisms available to larvae in the ocean is critical. Storms at sea may dilute and disperse available food below critical limits.

76. Lasker, R. 1978. Ocean variability and its biological effects--regional review--Northeast Pacific. Rapp. P.-v. Réun. Cons. int. Explor. Mer, 173:168-181.

Review of research, present and past, to correlate oceanographic conditions and fisheries. Increased upwelling favors fishing for several species when lagged 1/2 to 1 1/2 years.

Strong upwelling can be detrimental if it breaks up phytoplankton patches, example cited in anchovy.

Rainfall at spawning, hours of sunlight, and time when fry are moving offshore, can be positively correlated with even-year stock size of pink salmon along British Columbia coast. Suggests that time series analyses should be used for such studies.

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

Proposes that monitoring of aggregation of potential larval fish food particles in spawning season along with pertinent environmental variables may be practical way to predict relative recruitment success of pelagic fish. Onset and duration of upwelling events are important, and have negative effects on larval survival and recruitment by replacing dinoflagellates with smaller diatoms which cannot meet dietary needs of larvae. Stratification and stable conditions are required to provide suitable quantity of proper size phytoplankton.

78. Lasker, R. 1981. Factors contributing to variable recruitment of 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.

Prediction of year-class strength of northern anchovy depends on wind stress, direction, duration, number of repeat episodes, depth of ocean stress mixing, and degree of patchiness of larvae and food.

Stability of ocean's upper layers during anchovy spawning season is essential for aggregation of nutritionally suitable food coinciding with anchovy larvae in time and space.

Two years contrasted. Strong upwelling in 1975 obliterated food source and resulted in poorest year-class in 16 years. Calm seas and strong stratification in 1976 made food plentiful and the strongest year-class in 16 years.

79. Lasker, R. 1980. Prediction of recruitment paper presented to the Office of Technology Assessment, U.S. Congress, April 1980, Seattle, Washington. 8 pp.

Review of papers on author's previous work dealing with anchovy recruitment and relation of first feeding larvae to oceanographic conditions. Cites need to expand current work away from clupeoid species to include others, and need for management to take into consideration the effect of major environmental factors on larval fish and their food.

80. Lasker, R. and P. E. Smith. 1977. Estimation of the effects of environmental variations on the eggs and larvae of the northern anchovy. CalCOFI Reports, XIX:128-146.

Changes in anchovy spawning are compared to seasonal and annual variations in sea water temperature, vertical temperature gradients, upwelling, California current, flushing rate of Southern California Bight and secondary production.

Spawning habitat of anchovy is patchy and changes year to year. Survival of first feeding larvae is linked to coincidences between food patches and larval patches. Adequate production is not sufficient, stable oceanographic conditions must exist.

81. Laurs, M. and R. Lynn. 1977. Seasonal migration of albacore T. alalunga, into North American coastal waters, their distribution, relative abundance and association with Transition Zone waters. Fish. Bull. 75(4):795-822.

When East Pacific Transition Zone (Sub-Arctic/Sub Tropical) is distinct, albacore migrate along a "corridor" and are concentrated, often remaining in the Transition Zone for some time. When boundary is diffuse, migration is over broader area, and albacore move rapidly to shore. Reasons are temperature preference, aggregation of food, and thermal gradients, all possibly integrated. Prediction of Transition Zone structure permits operational fishery decisions by industry.

82. Lett, P. F., A. C. Kohler and D. N. Fitzgerald. 1975. Role of stock biomass and temperature in recruitment of Southern Gulf of St. Lawrence Atlantic Cod, Gadus morhua. J. Fish. Res. Board Can. 32:1613-1627.

Abundance of cod eggs is due in part to the condition factor (food abundance) of the spawning adults, with faster growing individuals producing more eggs. Larval survival and hence year class strength are related to temperature, with an optimum value around 7.1°C. Increased survival is related to between years temperature increase.

Temperature effects are direct through bioenergic responses, and indirect, by controlling food supply.

Recruitment is based mainly on parent stock and secondarily on temperature.

83. Lett, P. F. and A. C. Kohler. 1976. Recruitment: a problem of multispecies interaction and environmental perturbations, with special reference to Gulf of St. Lawrence Atlantic herring (*Clupea harengus harengus*). J. Fish. Res. Board Canada. 33:1353-1371.

Used surface water temperature at one point in Gulf of St. Lawrence as an input for stochastic model for herring along with predation and competition from Atlantic mackerel. Temperature and abundance of 0 age group mackerel affected herring growth rate, but total herring biomass and total pelagic biomass didn't.

84. Longhurst, A., M. Colebrook, J. Gulland, R. LeBrasseur, C. Lorenzen and P. Smith. 1972. The instability of ocean populations. New Scientist, 1 June 1972, pp. 500-502.

Authors cite need for understanding of natural physical environmental marine biota interactions before pushing "eco-catastrophes" and overfishing as causes of stock declines.

While man's "chemical invasion" of the ocean is a real and serious threat, the effects of climate changes or trends are often the "forcing mechanisms" of population change. Separating the two influences is one of science's biggest problems.

Examples of natural events are given using the Northwest Atlantic tilefish and haddock, Peruvian El Ninos, Northeast Pacific zooplankton, West Greenland codfishery, Pacific anchovy and North Sea zooplankton. The ocean is a changing environment with the changes either slow and covert or sudden and dramatic.

85. Lough, R. G., G. R. Bolz, M. D. Grosslein, D. C. Potter. 1981. Abundance and survival of sea herring (Clupea harengus) larvae in relation to environmental factors, spawning stock size, and recruitment for the Georges Bank area, 1968-1977 seasons. Rapp. P.-v. Réun. Cons. int. Explor. Mer, 178:220-222.

Herring catch increased until 1968, then decreased to zero. In addition to fishing pressure, fluctuations are believed to be caused by differential larval mortality. Spawning activity may be enhanced by "warmer" autumn bottom temperatures. During decade, center of spawning activity has shifted from eastern Georges Bank to western Georges Bank and Nantucket Shoals. Currents are different and subtle changes in current patterns may cause "extreme" fluctuations in recruitment. Larval survival higher during SW winds-onshore transport. Gulf Stream rings and offshore wind driven transport remove larvae from Banks- lost offshore and/or starve. Analysis of 10 year mean Ekman values show SW vector.

86. Markham, C. G. and D. R. McLain, 1977. Sea surface temperature related to rain in Ceara, north-eastern Brazil. Nature 265(5592):320-323.

Rainfall in Ceara, Brazil is correlated with sea surface temperature in the S. Atlantic Ocean. Authors suggest that Sea Surface Temperatures can be used as rainfall predictor. Warm Ocean Temperatures raise the Trade Wind Inversion Layer and hence the moisture layer.

87. Martin, W. R. and A. C. Kohler. 1967. Variation in recruitment of cod (Gadus morhus L.) in southern ICNAF waters as related to environmental changes. ICNAF Spec. Publ. Bol. 6:833-845.

Developed negative correlation between sea surface temperatures in New England, Nova Scotia and Gulf of St. Lawrence with cod landings in ICNAF area 5. Constructed linear equation, in time, for each data set, then conducted statistical analysis of "residuals" from linear plots, in an attempt to refute notion that the two data sets were merely coincident independent linear trends. Correlation coefficients were not particularly high (0.38 to 0.75).

88. McGuirk, J. R. 1978. Planetary-scale forcing of the January 1977 weather. Science 199:293-295.

Weather anomalies that occurred in the United States during January 1977 were typical of a planetary-scale wave phenomenon called stratospheric sudden warming (SSW). These are accompanied by specific changes in weather: Blocking ridges (intensified high-pressure cells) develop over subtropical oceans and move northward. When the SSW is strong, as in January 1958, 1963 and 1977, the accompanying weather anomalies can be unusually severe.

89. McHugh, J. L. 1976. Effects of climatic change on fisheries. National Climate Program Act hearings before the Subcommittee on the Environment and Atmosphere of the Committee on Science and Technology, U. S. House of Representatives. 94th Congress, 2nd Session, May 18-27, 1976. Contr. No. 177 of the Marine Sciences Research Center, State University of New York at Stony Brook. New York Sea Grant Institute, 99 Washington Ave., Albany, N. Y. 12246.

Gives examples of climatic change and impact on yellowtail flounder, oyster, soft clam and Pacific salmon.

90. McLain, D. and F. Favorite. 1975. Anomalously cold winters in the southeastern Bering Sea, 1971-1975. Marine Science Communications, Basic and Applied.

Cold SST caused atmospheric shift in winds. Northerly winds brought ice further south. Colder conditions reduced salmon egg and larval survival.

1. Delays return of adult to spawn
2. Cold weather forms "ice dams" in gravel which erodes surface and exposes eggs
3. Reduced water flow, hence O_2
4. Reduced growth rate in juveniles (when <4°C - 1971-73 slowest growth on record)

91. Mearns, A. J. 1980. Changing Coastal Conditions: 1979 Compared to the past 25 years. Coastal Water Research Project, Biennial Rept. 1979-1980, pp. 273-284.

Long term (1956-1979) temperature and transparency trends and fluctuations (variation and deviation) were evaluated and related to upwelling, rainfall, and commercial catch (anchovy, mackerel, swordfish, and demersal species). Temperature changes and occurrence of dinoflagellates are also discussed. Temperature increases are reflected by decreases in red dinoflagellate, anchovy and demersal fishes. Pacific mackerel on the other hand have increased.

92. Miller, F. R. and R. M. Laurs. 1975. The El Nino of 1972-1973 in the Eastern Tropical Pacific Ocean. Bull. Inter-Amer. Trop. Tuna Comm. 16(5):403-448.

Seasonal cooling of surface waters failed to develop in 1972. Anomalies of 3-4°C spread over most of the eastern Tropical Pacific. This El Nino is compared with the 1957 and 1965 occurrences. The meteorological factors leading to the relaxation of the SE trades are discussed.

93. Mitchell, J. M. 1953. On the causes of instrumentally observed secular temperature trends. J. of Meteorol. 10(4):244-261.

Considers measured temperature records (ca. 1890) as indicators of recent climate change or micro-climate. Concludes large fluctuations can be due to instrument or human error.

94. Murty, A. V. S. and M. N. Vishnudatta. 1976. The seasonal distribution of some oceanographic parameters off southwest coast of India relevant to pelagic fisheries. Indian J. Fish. 23(1 and 2):97-104.

Seasonal differences in thermocline, dissolved oxygen, temperature and salinity for the coast of India are discussed.

The distribution of the two major pelagic fishery species is associated with high salinity, moderate temperature and deep thermocline. The catches of the oil sardine and mackerel are high in the winter when these conditions prevail, however, their spawning does not appear to be associated with the high salinity. The dissolved oxygen content did not change seasonally.

95. Murray, T., S. LeDuc, and M. I. Ingham. 1981. Impact of climatic factors on early life stages of Atlantic mackerel, Scomber scomberus: An application of meteorologial data to a fishery problem. J. Applied Meteor. (In Press)

Ekman transport is demonstrated as a probable source of variability in Atlantic mackerel recruitment in the Mid-Atlantic Bight. On shore transport during spawning results in enhanced recruitment while offshore transport results in reduced recruitment. Fluctuations in spring temperatures can cause earlier or later spawning and windows of transport need to be adjusted accordingly.

96. Namias, J. 1981. The Weather: From Sea to Sky. Oceans 14(6):44-53.

A basic fundamental review paper on meteorology and sea-air interaction for the non-meteorologist scientist. Namias discusses how displacements in the polar front effect weather, and how sea surface temperature anomalies can be responsible for its displacement. The global teleconnection between oceanic and atmospheric interactions is emphasized.

97. Nelson, W., M. Ingham and W. Schaaf. 1977. Larval transport and year-class strength of Atlantic menhaden, *Brevoortia tyrannus*. Fish. Bull. 75(1):23-41.

A Ricker spawner-recruit model was developed for the menhaden. From this a "survival index" was regressed against zonal Ekman transport and was found to be significant. Ekman transport is responsible for carrying spawning into favorable nursery grounds or out to sea.

98. Newell, R. E. 1979. Climate and the ocean. Amer. Sci., Vol. 67:405-416.

General review of climate and causes of fluctuations due to changes in energy balance. Role of ocean considerable due to latent heat capability as main source for atmospheric heat. Most incident solar radiation goes into ocean. Oceanic currents transport heat poleward and acts as buffer to short term changes.

Wind stress (subsequently upwelling) controls SST, as does small scale turbulent mixing (in upper 20-100 m). Non-seasonal changes in SST anomalies are discussed. Namias theory of fluctuations in standing atmospheric waves causing changes are compared with those (e.g. Ratcliffe and Murray) that propose SST produce atmospheric pressure anomalies.

99. Norcross, B. L. and H. M. Austin. 1981. Climate scale environmental factors affecting year class fluctuations of Chesapeake Bay croaker, *Micropogonias undulatus*. VIMS Special Scientific Rept. 110. 78 pp.

Abundance of young-of-the-year croaker in the York River, Virginia, correlate with average January-February water temperatures allowing a prediction of their summer abundance.

100. Ottestad, P. 1942. On periodical variations in the yield of the Great Sea fisheries and the possibility of establishing yield prognoses. Rept. on Norwegian Fish and Mar. Invest. 7(5):3-11.

Notes periodic growth patterns in trees related to corresponding patterns of climate change and suggests that the same mechanisms may influence variations in fisheries. Uses catch of Norwegian skrei (Gadus callarias) as example.

101. Ottestad, P. 1960. Forecasting the annual yield in sea fisheries. Nature 185(4707):183-185.

Suggests forecasting fishery yields using aggregate sine functions of catch, similar to tree ring studies. Accurate forecasts would not be possible but trends would.

102. Owen, R. W. 1980. Patterning flow and organisms in the larval anchovy environment. pp. 167-200. In Workshop on the Effects of Environmental Variation on the survival of Larval Pelagic Fishes. IOC Workshop Rept. No. 28. Sharp., G.: Editor. Lima, Peru April-May, 1980.

Patterned circulation (eddies and fronts) establishes localized, or patchy concentrations of microorganisms. These patterned concentrations support the densities necessary for first feeding larvae. Horizontal and vertical patch structure and concentration are dependent upon circulation and may be predictable to an extent such that year class may be predicted also.

103. Parrish, R. H. 1976. Environmental-dependent recruitment and exploitation simulation of the California current stocks of Pacific mackerel (Scomber japonicus). Ph.D. dissertation, Oregon State University, Corvallis, Oregon.

Variations in year-class size and later fished stock, is related to fluctuations in upwelling and off-shore surface. convergence on spawning grounds.

104. Parrish, R. H. and A. D. MacCall. 1978. Climate variation and exploitation in the Pacific mackerel fishery. State of Calif. Dept. Fish & Game. Bull. 167. 110 pp.

Spawning stock size, recruitment, and catch data for Pacific mackerel were run using Ricker, Cushing, and Beverton and Holt models. The Ricker model provided the most accurate estimation. When it included upwelling, transport or sea level data the forecast catch was improved. The authors state that the environmental effects exacerbate the troughs and peaks.

"...recruitment models that include both density-dependent and environmental-dependent components are considerably better than the density-dependent recruitment functions in predicting recruitment in a given year."

105. Parrish, R. H., C. S. Nelson and A. Bakun. 1981. Transport mechanisms and reproductive success of fishes in the California current. Biol. Oceanog. 1(2):175-203.

Coastal spawning species having pelagic larvae tend to spawn during winter when surface wind drift is directed toward the coast. Regions characterized by vigorous upwelling, and hence higher productivity, are characterized by offshore transport and a paucity of locally spawning species with epipelagic eggs.

Closed gyral circulation patterns foster larval retention and favor spawning in the southern California Bight and Baja California.

Anomalies in drift patterns can account for variations in yearclass strength.

106. Pauly, D. 1980. On the interrelationship between natural mortality, growth parameters, and mean environmental temperatures in 175 fish stocks. J. Const. Int. Explor. Mer. 39(2):175-192.

Coefficients of natural mortality (M) are compiled for 175 stocks of fish from L_∞ and W_∞, and K from the von Bertalanffy growth formula using mean annual water temperatures as a modifier.

107. Pearson, J. C. 1948. Fluctuations in the abundance of the blue crab in Chesapeake Bay. USF&WS Res. Rept. 14, 26 pp.

Annual fluctuations in commercial landings of blue crab "may be" related to strength and timing of river discharge from the Chesapeake Bay tributaries. Heavy discharge during the spawning season is bad, and light discharge is good. Excessively cold winters may also have an effect.

108. Pella, J. J. 1979. Climate trends and fisheries. In: Predator-Prey System in Fisheries Management, pp. 35-46, H. Clepper, ed. Sport Fishing Institute, Washington, D.C.

General review article of climate and fisheries research in support of management. Cites numerous examples of fluctuations of climate and gives case histories of fluctuations in population size of halibut, Pacific salmon, sardine and menhaden.

Emphasizes that management agencies may need to regulate fisheries to avoid over-exploitation during periods of adverse climatic effects, hence need for predictive ability.

109. Peter, K. J. 1981. Influence of environmental changes on the distribution and abundance of ichthyoplankton in the Bay of Bengal. Rapp. P.-v. Réun. Cons. int. Explor. Mer, 178:210-216.

Changes in distribution and seasonal abundances of fish eggs and larvae coincide with changes in surface currents (due to monsoon winds) and upwelling. Northeast monsoons shift the concentrations of eggs and larvae towards coastal waters from the offshore region; and higher ichthyoplankton concentrations are reported along the eastern and western boundaries of the Bay associated with upwelling.

110. Peterson, W. T. 1973. Upwelling indices and annual catches of Dungeness crab, Cancer magister, along the west coast of the United States. Fish. Bull. U. S. 71:902-910.

Empirical relationship between intensity of upwelling and crab fishery is developed with strong crab catch lagging strong upwelling indices by 1.5 years.

111. Peterson, W. T. and R. L. Smith. 1979. Upwelling indices and the Oregon Dungeness crab fishery catches. Proc. from the Climate and Fisheries Workshop, COMS/URI, March 1978. pp. 132-133.

Discusses earlier work (Peterson, 1973, above) relating empirical upwelling data to crab abundance and suggests that time lags were due to slow energy transfer through food web. This paper suggests an additional component in the 1.5 year lag, that of molting. Molting must be timed with high food availability, following upwelling.

Weak upwelling periods: 1960-1963

Poor crab landings: 1961-62 through 64-65

High upwelling periods: 1964-1968

Record landings: 1965-66 through 70-71.

112. Pielou, E. C. 1981. The usefulness of ecological models: A stock-taking. Quart. Rev. Biol. 56:17-31.

Compares ecological methodologies of investigating and modeling. Modeling is the symbolic representation in mathematical equations of an ecosystem or its components. Of use to climate scale studies is a discussion of time series forecasting which expresses the components as time domain yield forecast equations and spectral analyses. Time domain yield forecast equations are considered a form of modelling whereas spectral analyses is a form of investigation as it yields empirical evidence of causes. Short comings of time series are discussed including the need for a large number of past observations and the small lead time for precision forecasts.

Spectral analyses are useful in determining the necessary frequency of observations in a time series.

113. Quinn, W. H. 1976. Use of southern oscillation indices to assess the physical environment of certain tropical Pacific fisheries. Pages 50-70 in Proceedings of the NMFS/EDS Workshop on Climate and Fisheries, April 26-29, 1976.

Anomalous equatorial Pacific meteorological and oceanographic conditions (e.g. El Nino) are the result of certain large-scale changes in atmospheric and oceanic circulation. These changes appear to be closely associated with variations in amplitude and period of an irregular interannual fluctuation in the atmosphere circulation pressure gradient called the Southern Oscillation. Changes in the index of the Southern Oscillation are monitored and predicted through time series of atmospheric pressure indices.

114. Rae, K. 1957. A relationship between wind, plankton and haddock brood strength. Bull. Mar. Biol. 6(38):248-269.

Haddock recruitment is dependent upon wind functions. Larvae carried over open water fail to settle out, with subsequent reduction in yearclass strength.

115. Radovich, J. 1961. Relationships of some marine organisms of the Northwest Pacific to water temperatures: particularly during 1957 through 1959. St. of Calif. Dept. Fish & Game Mar. Res. Op. Fish Bull. No. 12.

Environmental variations change the distribution of fish as evidenced by the warming trend in California coastal waters during 1957-1959, and episodes of previous warm water years. Water temperatures have a greater effect on fisheries that exist near the edge of the population range. Fluctuations in water temperature and overfishing may all affect fisheries to a degree, but they may also mask one another. Studies are cited reporting changes in individual species distribution in relation to fluctuations in water temperature over time. Increased water temperatures result in warm water species moving further north.

116. Revelle, R. 1979. Climate change and the ocean. Presentation to the Joint SCOR/IOC Committee on Climate Changes and the Ocean (CCCO), 11th Session, IOC Assembly. UNESCO, Paris, France. 7 pp.

General review of climate scales, ocean interactions, and effects on biota.

Author outlines five panel areas of focus:

1. Oceanographic program
2. Sea ice
3. Climate and marine ecology
4. High resolution paleoclimatology
5. Ocean/atmospheric models

117. Richkus, W. A., J. K. Summers, T. T. Polgar, and A. F. Holland. 1979. A review and evaluation of fisheries stock management models. Rept. from Martin Marietta Corp. to Coast. Res. Div., Md. Tidewater Admin., MdDNR. 73 pp.

Evaluates MSY and spawner/recruit models for Chesapeake Bay estuarine dependent species. Suggests that for many species, particularly clupeids, environmental variables should be statistically related to recruitment and yield. Proposes that autoregressive models rather than correlative should be considered for stock-environment recruitment relationships.

118. Russell, F. S., A. J. Southward, G. T. Boalch and E. I. Bitler. 1971. Changes in biological conditions in the English Channel off Plymouth during the last half century. Nature (234):468-470.

Period of 1920 to 1940's shows reduction in herring, cod and ling coincident with reduction in Calanus and phosphorous concentrations.

During the 1940's to 1964 pilchard eggs were abundant, then in 1964 to 1971 pilchard eggs disappeared again, and herring, cod and ling reappeared.

The authors suggest "warming of the Arctic would affect circulation in the North Sea and let Atlantic Ocean waters extend further north." Using winter PO_4 as an index, winter herring hatch are inversely related to pilchard hatch the following summer.

119. Saila, S. B., W. Wigbout and R. S. Lermit. 1980. Comparison of some time series models for the analysis of fisheries data. J. Const. Inst. Explor. Mer. 39(1):44-52.

Time series models of rock lobster (Jasus edwardsii) CPUE were evaluated. An auto-regression integrated moving average (ARIMA) was found most suitable for 12-month forecasts.

120. Schubel, J. R. and D. J. Hirschberg. 1978. Estuarine graveyards, climate change, and the importance of the estuarine environment. In: Estuarine Interactions, Academic Press, New York. pp. 285-303.

Authors suggest that the concept of "estuarine dependency" is overblown as estuaries are not a permanent geological feature only being abundant during climatic interglacials (10% of the time).

121. Schultz, S. 1978. Weather, climate and fish stocks. EDIS J., Nov. 1978, pp. 14-18.

Author cites documented success of climate-crop relationships and need for studies between climate and weather changes and changes in fish stocks. Reviews past papers by Russell, Cushing, Johnson, Quinn, and others on climate/fisheries relationships; and current NOAA research activities.

122. Schultz, S. 1979. Sea-surface temperature and climate. EDIS Magazine 10(6):7-9.

Climatic variations often arise from fluctuations in poorly understood sea-air interactions. Empirical studies suggest that sea-surface temperature fluctuations may be the key to understanding the patterns. Factors controlling SST include changes in:

1. solar radiation
2. evaporation (surface winds)
3. depth of mixed layer affected by 1 & 2, and
4. heat transfer horizontally & vertically

123. Seckel, G. 1972. Hawaiian-caught skipjack tuna and their physical environment. Fish. Bull. 72(3):763-787.

Seasonal shifts in Pacific water masses can be used as a predictor for skipjack abundance in the Hawaiian live bait fisheries. The skipjack are "advected" into Hawaiian waters with the water mass. Salinity changes in early spring is the best predictive index, an early shift, a good year, late shift, a bad year.

124. Seckel, G. 1976. Climate oceanography in the Pacific. Proc. NOAA Symposium on Ocean Aspects of a Climate Program. Boulder, Colorado. May 1976, 35 p.

Time series data are necessary in order to discern climatic scale events. Oceanographers find work difficult due to lack of marine time-series and lack of any ocean data. Atmospheric proxy data exist however with good continuous series and areal coverage.

125. Sette, O. E. 1943. Biology of the Atlantic mackerel (Scomber scomber) of North America. Fish. Bull. 50(38):149-237.

Pursues hypothesis that "infant mortality" is the key to year class success. Studies 1932 year class by extensive field sampling of eggs, larvae and post larvae, a year class that failed so he looked for the reason. Found that no single stage of development was outstandingly critical, but seemed to be high mortality rate throughout. Probable causes: 1) dearth of food (low zooplankton population), 2) unfavorable winds from NE drove larvae away from nursery grounds off southern New England instead of toward them, as a SW wind would.

126. Sette, O. 1959. The long term historical record of meteorological, oceanographic, and biological data. CalCOFI Repts., Vol. VII, pp. 181-194.

"... . the events affecting the fisheries as originating in the atmospheric circulation, operating through their direct effects on the properties of sea water and indirectly by modifying the oceanic circulation, and these, in turn, affecting our marine animal populations, both directly and indirectly through the chain of plant populations."

Historic review of fishery oceanography and time series applications.

127. Setzler, E. M., J. A. Mihursky, K. V. Wood, W. R. Boynton, T. T. Polgar and G. E. Drewry. 1981. Major features of ichthyoplankton populations in the upper Potomac estuary: 1974-1977. Rapp. P.-v. Réun. Cons. int. Explor. Mer, 178:204-206.

Peak larval striped bass abundance is found in April, at or above the area of peak spawning activity. Production of successful year classes appears to be non-density dependent with "colder" winters and "higher" spring runoff as prerequisites for increased larval survival.

128. Simpson, A. C. 1953. Some observations on the mortality of fish and distribution of plankton in the southern N. Sea during the cold winter, 1946-47. J. du Conseil, Vol. 19, pp. 150-177.

During January 1974, a high pressure system over Scandinavia caused strong easterly winds over North Sea for approximately 4 weeks. This displaced several species from their normal spawning grounds (dab, cod, flounder) and delayed hatching. Dead fish (cod, plaice, and dab) were found in several cruises. A similar event occurred in 1929.

129. Sissenwine, Michael P. 1977. A compartmentalized simulation model of the southern New England yellowtail flounder, *Limanda ferruginea*, fishery. Fish. Bull. 5(3):465-482.

Author develops a complex simulation model of the yellowtail fishery using an input of average annual air temperature at Block Island with several biological variables. The model accounts for 83.5% of variability in yield, using linear stock-recruitment functions, and 83.2% using density independent functions.

130. Sjöblom, V. 1978. The effect of climatic variations on fishing and fish populations. Fennia (150):33-37.

The effects of climate variation are felt "most clearly" in the case of pelagic fish populations (herring, anchovy, menhaden, tuna, mackerel). Spring spawning herring are most abundant following severe winters (1926-1930, 1940-1950) and autumn spawners during milder winters (1931-1939, 1951-1957). The reason proposed is that plankton is more abundant during summers following severe winters.

131. Skud, B. E. 1981. Interactions between pelagic fishes and the relation of dominance to environmental conditions. ICES C.M. 1981/H:60 Pelagic Fish Comm., 11 pp.

Reviews classical papers on several species (anchovies, herring, sardine, mackerel) and environmental interactions causing changes in dominance. Cites alteration of dominance by pilchard and herring (Cushing and Dickinson, 1976), mackerel and herring (Lett and Kohler, 1976) and sardine and anchovy and discusses possible climatic and interspecies interactions causing changes.

132. Smith, P. E. and R. W. Eppley. 1982. Primary production and the anchovy population in the Southern California Bight: Comparison of time series. Limn. and Oceanog. 27(1):1-17.

Time series analyses of anchovy biomass (1951-1979) and primary production (1920-1979) showed both were low during climatically warm years (1957-1958). Primary production reflects the carrying capacity of these waters for lower trophic level consumers. Fifty percent of variation in anchovy larvae is explained by variations in primary productivity during the same quarter, and zooplankton standing stock three quarters earlier.

133. Smith, P. E., L. E. Eber and J. R. Zweifel. 1981. Large scale environmental events associated with changes in the mortality rate of the larval northern anchovy. Rapp. P.-v. Réun. Cons. int. Explor. Mer, 178:200.

An oceanographic indicator of recruitment success for northern anchovy appears to be January 30-meter temperatures. Good recruitment (mortality: 27%) occurs when temperatures are 14-16°C and poor when 12-13°C (mortality: 43%). The mechanism(s) is not known, however, mortality of yolk-sac and early larval stages are implicated during cold years.

134. Soutar, A. and P. Crill. 1977. Sedimentation and climatic patterns in the Santa Barbara Basin during the 19th and 20th centuries. Bull. Geol. Soc. Amer. Vol. 88:1161-1172.

Thickness of annual sediment laminations in the Santa Barbara Basin is compared to southern California drought-resistant free growth and to regional indices of rainfall and temperature.

Sedimentation rates are independent of temperature, but highly correlated to precipitation in the previous and current season.

135. Soutar, A. and J. Isaacs. 1973. Abundance of pelagic fish during the 19th and 20th centuries as recorded in anaerobic sediments off the Californias. Fish. Bull. 72(2):257-273.

Deposition of fish scales of sardine, anchovy, hake, saury and mackerel in Santa Barbara Basin sediments is generally in accord with available population estimates. Scale deposition vs. population rates suggests major fish productivity between 1925 and 1970 was substantially below pre-1925 levels.

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

Processed sea temperatures at International Hydro. Sta. E-1, south of Plymouth, England, and fishery CPUE data (hake and cod) with Fourier analysis and auto-correlation. Found 10-11 year cycles in both sets. Also found correlations between temperature, pilchard egg population, post-larval clupeids and phosphate concentrations.

137. Stolle, H. J. 1975. Climate change and the Gulf Stream. Term paper for Geog. 858, Univ. of Wisc., 32 pages.

Cartographic evidence of the Gulf Stream and its location over the last 400 years, Iceland temperatures and Iceland ice occurrence chronologies show a relationship. Increases in flow azimuth results in decreasing sea temperature. Flow azimuth of 100° corresponds with peaks in Iceland ice.

138. Stone, J. H., J. W. Day, Jr., L. M. Bahr and R. A. Muller. 1978. The impact of possible climate changes on estuarine ecosystems. pp. 305-321, Estuarine Interactions. Academic Press.

Climatic factors affecting productivity in estuaries are long term (sea level changes) and short term (temperature and precipitation). Short term changes are more important to estuarine management. Temperature fluctuations in Louisiana between 1940 and 1950 are on the order of $\pm 10^\circ$F ($\pm 5.6^\circ$C) which effectively shortened or lengthened the growing season. Wet and dry year water budgets varied by a factor of 3-5 with a concomitant variation in Louisiana commercial fishery landings by a factor of .70. Changes in the precipitation regime brought about migration of isohalines and changes in turbidity.

139. Storrow, B. 1947. Concerning fluctuations and the teaching of ecology. Report of the Dove Marine Laboratory, Third Series No. 9, pp. 7-580.

Nineteenth century cyclic phases for bluefish and weakfish are suggested with the Bluefish phase associated with seals, capelin and basking sharks; the Weakfish phase with herring, mackerel and menhaden.

bluefish - warm in Europe
weakfish - cool in Europe

140. Sutcliffe, W. H., Jr., K. Drinkwater and B. S. Muir. 1977. Correlations of fish catch and environmental factors in the Gulf of Maine. Jour. Fish. Res. Bd. Canada. 34:19-30.

Correlated catches of 17 species in ICNAF Statistical Area 5 with water temperatures in northern Gulf of Maine and Bay of Fundy. Consideration of fishing effort and selecting best lag times improved the correlations. No discussion of cause and effect interactions between temperatures and catches.

141. Talbot, G. B. 1954. Factors associated with fluctuations in abundance of Hudson River shad. Fish. Bull. 101, Vol. 56, pp. 373-413.

No correlation between size of annual run and Hudson River flow in May-July four to five years earlier. A relationship was found between the spring run and water temperature. The run occurred earlier in warm years, later in cool (ed. note - thus, in warm years the fishery is prosecuted for a longer time period, hence larger catches).

142. Taylor, C. C., H. B. Bigelow and H. W. Graham. 1957. Climate trends and the distribution of marine animals in New England. Fish. Bull. 57:293-345.

Discusses general warming trend in 1900-1940 period to sea water temperature trends at Boothbay Harbor, Maine. Relates landing statistics for mackerel, lobster, whiting, menhaden and yellowtail flounder to the air temperature and water temperature records. Range extensions of southern species are related to temperature trends. Points out weakness in the causal inferences which might be drawn from these data.

143. Templeman, W. and A. M. Fleming. 1953. Long term changes in hydrographic conditions and corresponding changes in the abundance

of marine animals. Int. Comm. Northwest. Atl. Fish. Annual Proc. 3:78-86.

Points out lack of good long-term hydrographic data in ICNAF areas 2 and 3. Uses air temperature record at Jorbay Airport, St. Johns, Newfoundland (1872-1952) and water temperature record at St. Andrews, N. B. (1920-1952). Visual correlation of temperature data (annual) with rough estimates of abundance data (catch, sightings) for mackerel, lobster, squid, billfish, capelin and cod.

144. Tont, S. A. 1974. Short term climatic fluctuations: Effects on diatom Biomass. Science 194:942-944.

During 1928 through 1939 three major blooms account for 85% of each year's biomass. Blooms coincide with upwelling. If upwelling takes place after a large influx of subtropical or tropical watermasses due to a slackening of the California Current the blooms are several orders of magnitude smaller than those observed when the current is strong.

145. Tont, S. A. 1978. Sea-level-air temperature correlations near a coastal zone. Nature, Vol. 276:171-172.

Long term (1906-1975) fluctuations in air temperature are closely correlated with similar changes in coastal (California) sea levels. These changes in air temperature are shown by previous studies to be due to changes in meridional winds, California sea level is also so affected, hence the relationship.

146. Tont, S. A. and D. A. Delistraty. 1980. The effects of climate on terrestrial and marine populations. CalCOFI Repts. XXI:85-89.

Variability in marine populations in the California current system is due largely to short term events (upwelling), longer term changes (water mass influxes), and climate fluctuations which change the physical environment regulating diatom and dinoflagellate blooms. These changes at the base of the food chain manifest in fluctuations of organisms farther up the chain.

147. Tsukayamak, I. and M. A. Alvarez. 1981. Fluctuations in the anchoveta spawning stock during the reproductive cycle of spring 1964-1978. IOC Workshop Report No. 28, p. 233-240 (In Spanish).

The decline of the anchoveta population is related to spawning biomass and water temperatures. The average length of the fish was 28% of normal in warm years (12.5 cm) versus cool years (14.0 cm). The proportion of spawners was smaller in relation to the size of the adult population in warmer years. The hypothesis is that temperature lowered the amount of available food, which caused competition, resulting in a lower condition index of the spawners, reduced fecundity, and less viable eggs.

148. Tucker, J. W. 1978. Larval development of four species of bothid flatfish in the _Citharichthys-etropus_ complex: _C. cornutus_, _C. gymnorhinus_, _C. spilopterus_, and _E. crossotus_. MS Thesis, Dept. Zoology, N.C. State University. 213 pp.

A discussion is developed concerning possible causes for year to year fluctuations in sciaenids in the Cape Fear River Estuary (in an appended section of this thesis, unrelated to bothids).

It is hypothesized that annual fluctuations in larval abundance are related to river discharge due to the relative vertical distribution of larvae in the water column.

149. Uda. 1952. On the relation between the variation of important fisheries conditions and oceanography conditions in the adjacent waters of Japan. J. Tokyo Univ. Fisheries. 38(3):364-389.

Poorest catches of Hokkaido herring were recorded when cold winters occurred 4 years earlier, these included 1866, 1869, 1884, 1902, 1905, 1913, 1926, 1935, and 1945. Herring lay eggs near shore and thus, the eggs are susceptible to extreme cold events.

150. Ulanowicz, R. E., M. L. Ali and A. Vivian. 1979. Climatic factors influencing commercial landings in Maryland. Cont. of CEES, Univ. of MD, EPA/SAV Contract Rept. 16 pp.

Multivariate correlations of commercial fish and shellfish harvests are made with air and water temperature, salinity, and precipitation, and produced results showing greater than 50% of variation could be explained by appropriate annual characterizations. A forty year environmental data record was used. Species examined included: oyster, blue crab, soft clam, striped bass, menhaden, alewife, and bluefish. Authors suggest that time series analyses may produce better forecast techniques.

151. Ulanowicz, R. E., W. C. Caplins and E. A. Dunnington. 1979. The forecasting of oyster harvest in central Chesapeake Bay. Estuarine and Coastal Mar. Sci., Vol. II: 101-106.

Also published as: Sea Grant Rept. from Univ. MD/CEES. 16 pp.

Multivariate analysis of 40 years of data on oyster, Crassostrea virginica, reveals variations in spatfall and seed planting densities explain 56% of variation in annual harvest four years later. Spatfall varies directly with cumulative high salinities during spawning season, and inversely with previous season's harvest.

152. Walford, L. 1946. Correlation between fluctuations in abundance of the Pacific sardine (Sardinops caerulea) and salinity of the sea water. J. Mar. Res. 6(1):48-53.

The size of a year class of sardines correlates with average daily summer surface salinities from 1934 to 1941. Year classes were best for the years where salinities were high. Salinity is proposed as an index of upwelling.

153. Walsh, J. J. 1976. The biological consequences of interaction of the climatic, El Nino, and event scales of variability in the eastern tropical Pacific. J. Rapp. P.-v. Reun. Cons. Perm. Int. Explor. Mer.

Marine communities respond to global oscillations at climatic ("centuries") and El Nino ("years") time scales by geographically relocating their abundance centers. Author suggests, however, that in addition to overfishing, storms interrupt larval food supply and cause failure of most clupeid fisheries.

154. Walsh, J. J., T. E. Whitedge, F. W. and Barvenik, C. D. Wirick, S. O. Howe, W. Esaias, and J. T. Scott. 1978. Wind events and food chain dynamics within the New York Bight. Limnol. Oceanogr. 23(4):659-683.

Time series of wind, current, nutrients, chlorophyll and zooplankton are used to examine the effects on phytoplankton in the vertical plane, and aggregations in the horizontal. Nutrient analyses suggest that the turbulence associated with storms provides one third of the nutrient demand. The relationship between storms and water column stability suggests a predictable structure for survival of herbivores and food chain transfer.

155. Welch, Walter R. 1968. Changes in abundance of the green crab, Carcinus maenas (L.), in relation to recent temperature changes.

Water temperature records at Boothbay Harbor are compared with measures of green crab abundance and soft clam harvest. As temperatures declined after the 1953 peak, green crab abundance decreased and soft clam catch increased. Crab response is apparently physiological, both on adult survival and reproductive success, and the reduction of crab population reduced predation on soft clams.

156. Wickett, P. 1975. Relationship of coastal water convergence and Fraser River discharge to migration of Fraser R. sockeye through Johnstone Strait, Pac. Biol. Sta., Nanaimo B. C. Rept. 32-7.

Predictive relationship between percentage of returning sockeye salmon passing between Vancouver Island and the mainland on their way to the river. Fraser River discharge and wind stress holding fresh water near the coast account for 70% of variability.

Rain at time of spawn and hours of sunlight can account for 89% of variance in stock size off British Columbia from 1930-1974 (per comm. to Rueben Lasker).

157. Wild, P. W. 1980. Effects of seawater temperature on spawning, egg development hatching success, and population fluctuations of the Dungeness crab, Cancer magister. CalCOFI Rep. XXI:115-120.

Dungeness crab egg and larvae survive best in the temperature range of 10 to 17°C. Analyses of fluctuations in coastal ocean temperatures and commercial landings three years later show a predictive relationship. Temperatures since 1957 have generally been too warm for good survival.

158. Williams, A. B. 1969. Penaeid shrimp catch and heat summation, an apparent relationship. F.A.O. Fish Rept. 57:643-656.

Good Gulf and East Coast shrimp fisheries follow warm winters and poor fisheries follow cold. (Note: cold of 1958 and 1976-77 were poor years). [*relate to Johnson and McLain]

159. Wojcik, F. J. 1978. Temperature-induced croaker mortality. Coastal Oceanogr. Climatology News 1(1):5.

Cites current (1977-1978) and previous (1958,1966) cold winter low temperature kills of young-of-the-year croaker Micropogonias undulatus in York River, Virginia (Editors note: Commercial catch in Virginia waters two years later (1979) seems to have been affected).

160. Wooster, W. S. 1980. Oceanography, ecology, and marine fisheries. Paper presented to the Office of Technology Assessment, U.S. Congress, April 1980, Seattle, Washington. 20 pp.

Express concern that in spite of stock-environmental interactions government agencies do little to support "fishery ecology". Discusses U.S. institutional shortcomings for lack of relevant research and recommends need for oceanographers and fishery biologists to communicate.

161. Wyrtki, K. 1975. El Nino, the dynamic response of the Equatorial Pacific Ocean to Atmospheric Forcing. J. Phy. Oceanogr. 5(4):572-584.

Proposes that warm waters associated with El Nino are the result not so much of a relaxation of SE Trade Winds, but more of strong Trades for two years prior to the event, piling up water in the Western Pacific. These waters return as an internal equatorial Kelvin wave which result in an accumulation of warm water off Ecuador and Peru. The event is a response of the Equatorial Pacific to atmospheric forcing by the Trade Winds.

162. Zaborski, J. and D. Haven. 1980. Oyster mortalities in the upper Rappahannock River and in the Virginia tributaries of the lower Potomac - their association with high river discharge and low salinity. Spec. Rept. in Applied Mar. Sci. and Ocn. Eng. No. 241, VIMS. 11 pp.

High river salinities during 1960's, the result of generally dry conditions in the eastern U.S., promoted many oyster growers in Virginia to plant seed oyster further upriver. A return to "wetter" conditions during the 1970's resulted in mortalities and poor growth as salinities dropped below 6-7 $^{o}/oo$ by the late 1970's.