Current Status and Historical Trend Indicators of Climate and Fishing Effects on the Bering Sea Ecosystem

Jennifer Boldt[1], Pat Livingston[2], Anne Hollowed[2], [1]JISAO, University of Washington, [2]Alaska Fisheries Science Center, NMFS, Seattle, WA

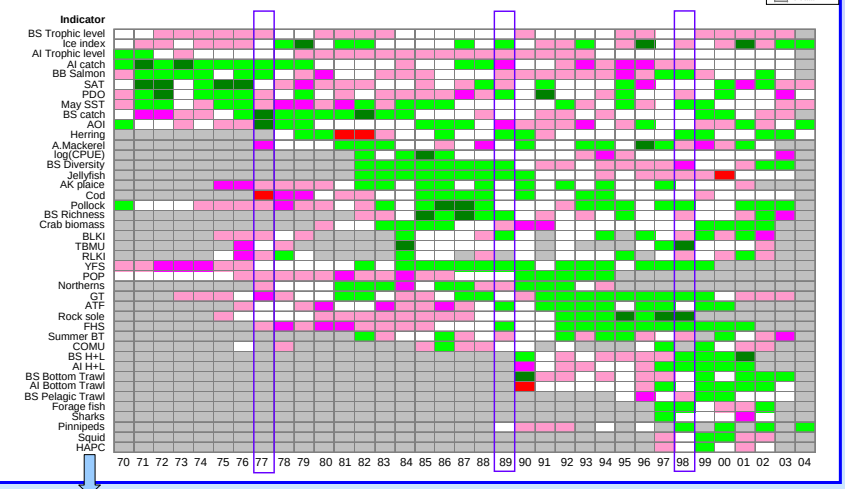
contact information: email: Jennifer.Boldt@noaa.gov phone: (206) 526-4693

Introduction

Both climate and fishing are agents of change that can affect the production and distribution of marine organisms in the North Pacific. It is well known that a major climate shift occurred in the North Pacific around 1976/77, a minor climate shift was observed in 1989, and another climate shift occurred in 1998/99. These climate shifts are reflected in ocean conditions, such as sea surface temperature, ice cover, and wind-driven transport. The relative importance of each of these climate shifts to physical conditions in the Bering Sea varies, as does their impact on the production and distribution of marine organisms. Fisheries can impact fish and ecosystems directly by selectivity, magnitude, timing, location, and methods of fish removals. There are other possible effects of fishing such as vessel disturbance, changes in nutrient cycling, the introduction of exotic species, pollution, unobserved mortality, and habitat alteration. The Ecosystem Considerations section of the Stock Assessment and Fishery Evaluation of the North Pacific Fisheries Management Council provides a current and historical perspective on status and trends of ecosystem components and ecosystem-level attributes using an indicator approach. Effects of fishing and climate can be categorized into three main ecosystem attributes that we strive to protect: diversity, energy flow and balance, and predator-prey relationships.

A visual tool to examine anomalies

This table is a visual tool used to examine indices of three ecosystem attributes (diversity, energy flow and balance, and predator-prey relationships), the physical environment, and others. This visual tool enables us to examine anomalies of ecosystem indices in relation to long-term average conditions and to see periods of change.



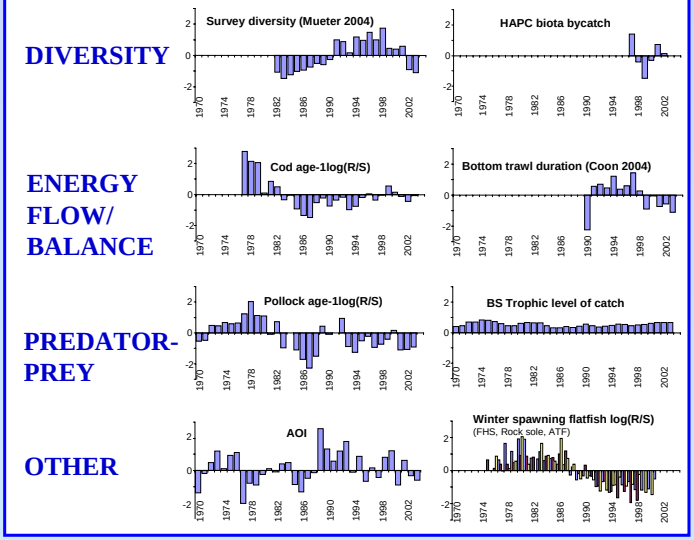
Data sources

Attribute	Index	Series	Description	Source
Predator-prey	BS Trophic level	1954-2003	Bering Sea trophic level of the catch	Livingston 2005
Physical Environ.	Ice index	1954-2004	A combination of 6 highly correlated ice variables	http://www.beringclimate.noaa.gov/index.html
Predator-prey	AI Trophic level	1962-2003	Aleutian Island trophic level of the catch	Livingston 2005
Energy flow	AI catch	1962-2003	Total catch Aleutian Islands	NPFMC 2004
Other	BB Salmon	1956-2003	Total catch of Bristol Bay salmon	Eggers 2004
Physical Environ.	SAT	1916-2004	Surface winter air temperature	http://www.beringclimate.noaa.gov/index.html
Physical Environ.	PDO	1901-2004	Pacific Decadal Oscillation	http://jisao.washington.edu/pdo/PDO.latest
Physical Environ.	MaySST	1970-2004	May sea surface temperature	http://www.beringclimate.noaa.gov/index.html
Energy flow	BS catch	1954-2003	Total catch Bering Sea	NPFMC 2004
Physical Environ.	AOI	1951-2004	Arctic Oscillation Index	http://www.beringclimate.noaa.gov/index.html
Predator-prey	Herring	1978-2004	Togiak herring age-4 recruits	West 2004
Predator-prey	A.Mackerel	1977-2002	Atka mackerel log-transformed recruit per spawning biomass	NPFMC 2004
Predator-prey	log(CPUE)	1982-2003	Total catch per unit effort of fish and invertebrates in bottom trawl surveys	Mueter 2004
Diversity	BS Diversity	1982-2003	Bering Sea groundfish diversity (Shannon-Wiener index)	Mueter 2004
Other	Jellyfish	1982-2003	Jellyfish biomass in survey catches	Walters 2004
Other	AK plaice	1975-1999	Alaska plaice log-transformed recruit per spawning biomass	NPFMC 2004
Energy flow	Cod	1977-2003	Pacific cod log-transformed recruit per spawning biomass	NPFMC 2004
Predator-prey	Pollock	1964-2002	Walleye pollock log-transformed recruit per spawning biomass	NPFMC 2004
Diversity	BS Richness	1982-2003	Bering Sea groundfish richness (avg. # species per survey haul)	Mueter 2004
Other	Crab biomass	1980-2002	Total crab biomass	Otto and Turnock 2004
Energy flow	BLKI	1975-2002	Black-legged kittiwake productivity (fledglings per egg) at St. Paul Island	D.E. Dragoo, USFWS, pers. comm.
Other	TBMU	1976-2002	Thick-billed murre productivity (fledglings per egg) at St. Paul Island	D.E. Dragoo, USFWS, pers. comm.
Energy flow	RLKI	1975-2002	Red-legged kittiwake productivity (fledglings per egg) at St. Paul Island	D.E. Dragoo, USFWS, pers. comm.
Other	YFS	1964-1998	Yellowfin sole log-transformed recruit per spawning biomass	NPFMC 2004
Other	POP	1960-1993	Pacific Ocean perch log-transformed recruit per spawning biomass	NPFMC 2004
Other	Northerns	1977-1993	Northern rockfish log-transformed recruit per spawning biomass	NPFMC 2004
Predator-prey	GT	1973-2003	Greenland turbot log-transformed recruit per spawning biomass	NPFMC 2004
Predator-prey	ATF	1978-2000	Arrowtooth flounder log-transformed recruit per spawning biomass	NPFMC 2004
Other	Rock sole	1975-1997	Rock sole log-transformed recruit per spawning biomass	NPFMC 2004
Other	FHS	1977-2000	Flathead sole log-transformed recruit per spawning biomass	NPFMC 2004
Physical Environ.	Summer BT	1982-2003	Summer bottom temperature	http://www.beringclimate.noaa.gov/index.html
Other	COMU	1976-2002	Common murre productivity (fledglings per egg) at St. Paul Island	D.E. Dragoo, USFWS, pers. comm.
Energy flow	BS H+L	1990-2001	Bering Sea Hook and line (longline) effort (number of hooks)	Coon 2004
Energy flow	AI H+L	1990-2001	Aleutian Islands Hook and line (longline) effort (number of hooks)	Coon 2004
Energy flow	BS Bottom Trawl	1990-2003	Bering Sea bottom trawl duration (24 hour days)	Coon 2004
Energy flow	AI Bottom Trawl	1990-2003	Aleutian Island bottom trawl duration (24 hour days)	Coon 2004
Energy flow	BS Pelagic Trawl	1995-2003	Bering Sea pelagic trawl duration (24 hour days)	Coon 2004
Predator-prey	Forage fish	1997-2002	Forage fish bycatch	Gaichas 2004
Predator-prey	Sharks	1997-2002	Shark bycatch	Gaichas 2004
Predator-prey	Pinnipeds	1989-2004	Non-pup Steller sea lion counts	Sinclair 2004
Predator-prey	Squid	1997-2002	Squid bycatch	Gaichas 2004
Diversity	HAPC	1997-2002	HAPC non-target catch Bering Sea/Aleutian Islands	Gaichas 2005

Results

- Many indices of climate, as well as indices of ecosystem diversity, energy flow and balance, and predator-prey relationships shifted after the 1977 and 1989 climate regime shifts.
- **Diversity** indices include diversity of species caught in NMFS bottom trawl surveys and bycatch of species that lack population estimates, such as HAPC (habitat of particular concern) biota. Diversity in NMFS bottom trawl surveys was higher in the 1990's, possibly due to shifts in species distributions and/or relative abundance (Mueter 2004). The time series of HAPC biota bycatch is too short to determine trends at this time.
- **Energy flow and balance** indices include bottom gear effort, which is an index of unobserved mortality, and cod population trends, which is an indicator of scavenger species that may be affected by fishing discards and offal. Bottom trawl duration has been lower in the last five years than it was in the 1980s (Coon 2004). Recent cod survival estimates appear to be near average with no apparent trend; there were high numbers of recruits per spawner prior to 1983.
- **Predator-Prey relationship** indices include the trophic level of the catch, which indicates whether large, top predators are being selectively removed ("fishing-down" the food web). Pollock survival is an index of forage fish trends (juvenile pollock are prey of other fish and adult pollock). There is no indication that "fishing-down" the food web is occurring. See below for pollock trends.
- **Climate** does affect organisms in the Bering Sea. For example, the shift in the Arctic Oscillation Index (AOI) in 1989 corresponded with a shift to higher survival of winter spawning flatfish due to favorable wind-driven transport of larvae to nursery grounds (Wilderbuer et al. 2002). Also, cod and pollock survival indices show similar trends, indicating that they may be responding to the same large-scale environmental forcing.

Ecosystem Attribute Examples



Conclusions

- Some Bering Sea ecosystem components responded to the 1977 and 1989 regime shifts.
  - Winter spawning flatfish larval transport and subsequent survival was positively affected by the 1989 regime shift seen in the Arctic Oscillation Index (AOI) (Wilderbuer et al. 2002).
  - Pollock and cod survival did not shift in 1977 or 1989, however, both have similar trends in survival, indicating they are responding to similar large-scale environmental forcing.
- No significant adverse impacts of fishing on the ecosystem relating to predator/prey interactions, energy flow/removal, or diversity were observed.

All literature cited and data presented are from the Ecosystem Considerations Appendix C of the Stock Assessment and Fishery Evaluation: http://www.afsc.noaa.gov/refm/stocks/assessments.htm