Juvenile halibut distribution and abundance in relation to environmental factors in the Gulf of Alaska and Bering Sea

Lauri Sadorus, Ian Stewart, Tom Kong

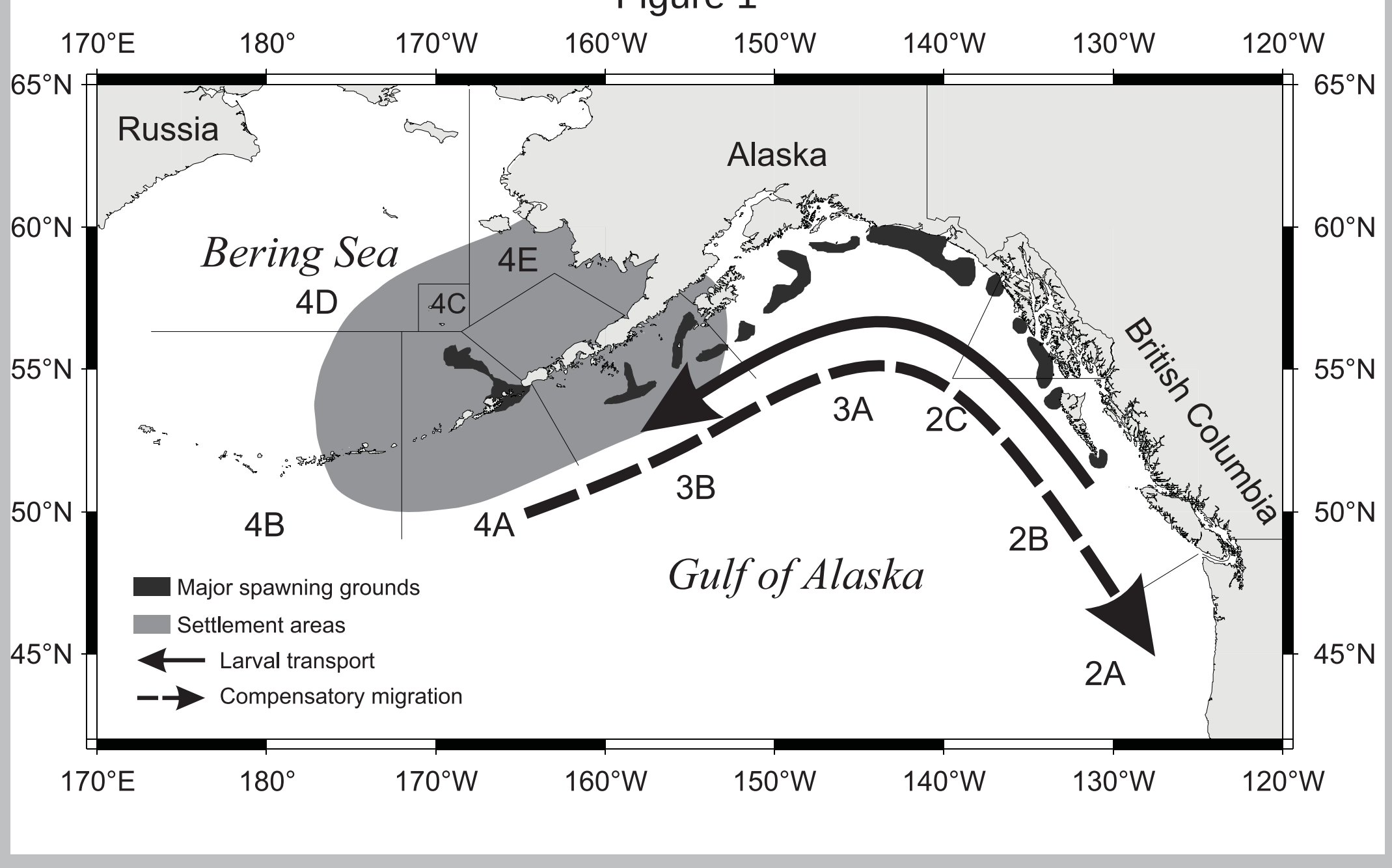
International Pacific Halibut Commission, 2320 W Commodore Way, Suite 300, Seattle, WA 98199, USA

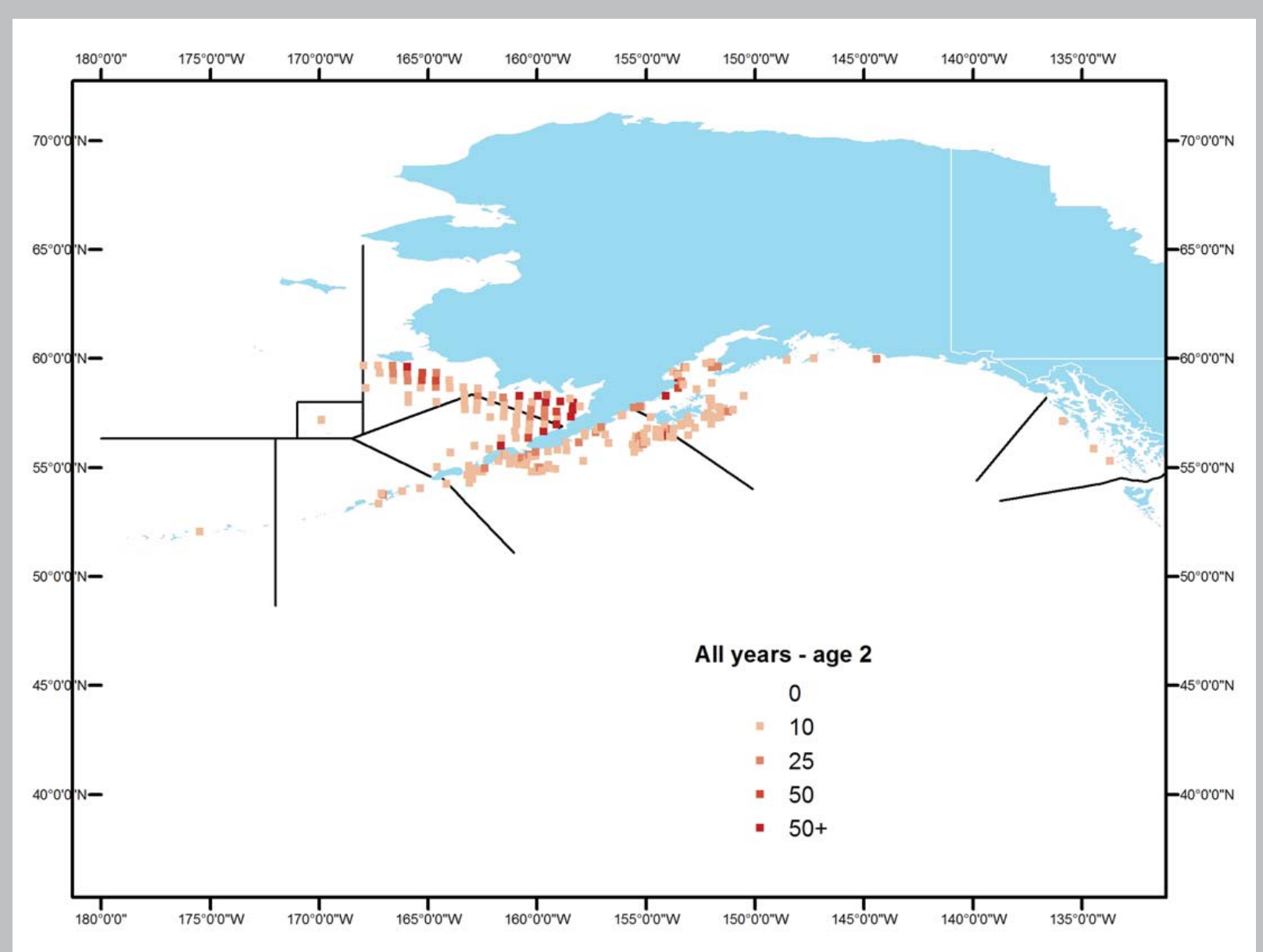
Introduction

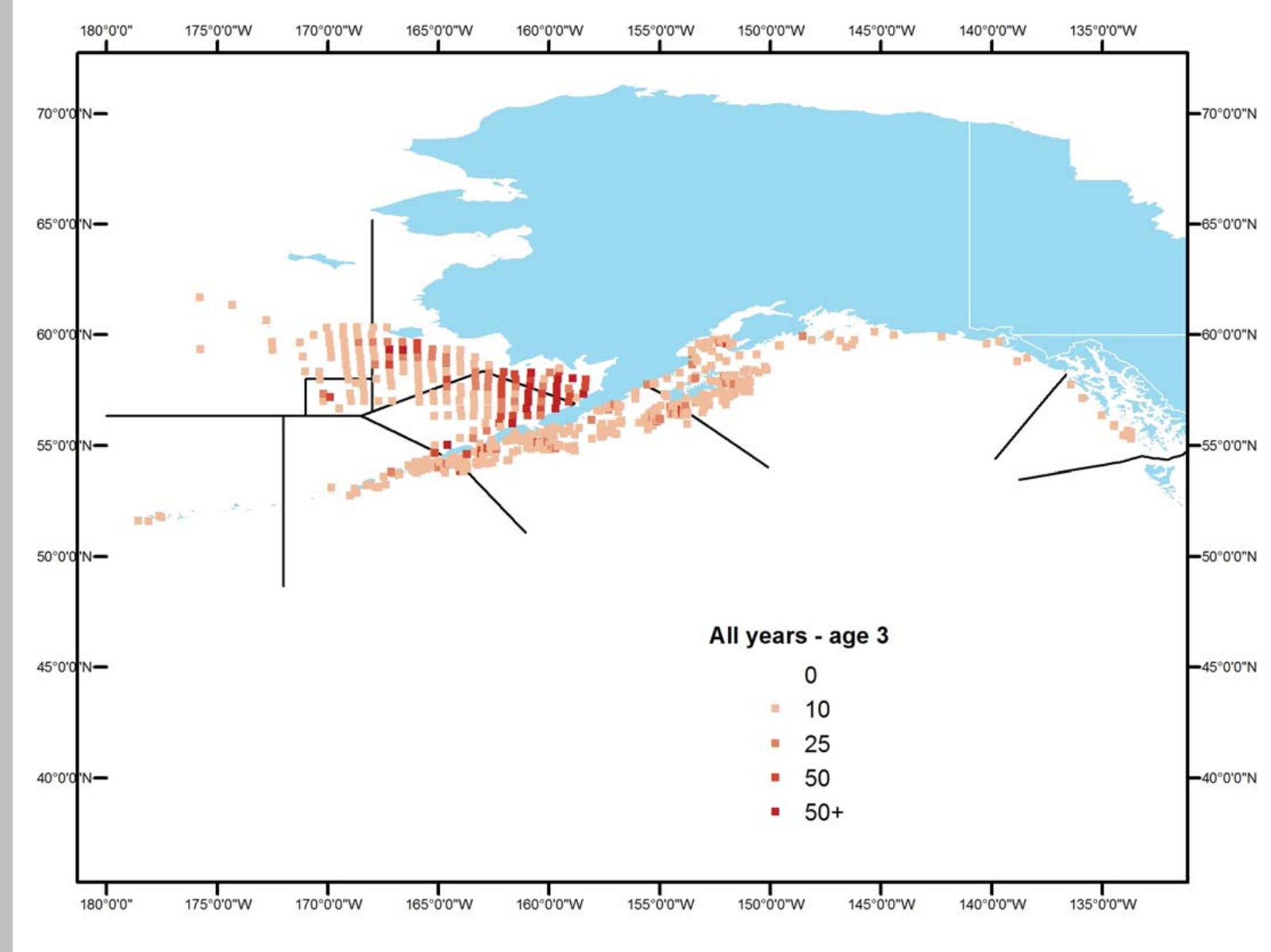
Monitoring of the juvenile Pacific halibut (*Hippoglossus stenolepis*) population is accomplished from data collected during the National Marine Fisheries Service (NMFS) groundfish trawl surveys. The adult halibut population is monitored closely through International Pacific Halibut Commission (IPHC) programs in order to estimate spawning biomass and the amount of exploitable biomass available for the commercial fishery, i.e. halibut > 82 cm fork length (Stewart and Martell 2014).

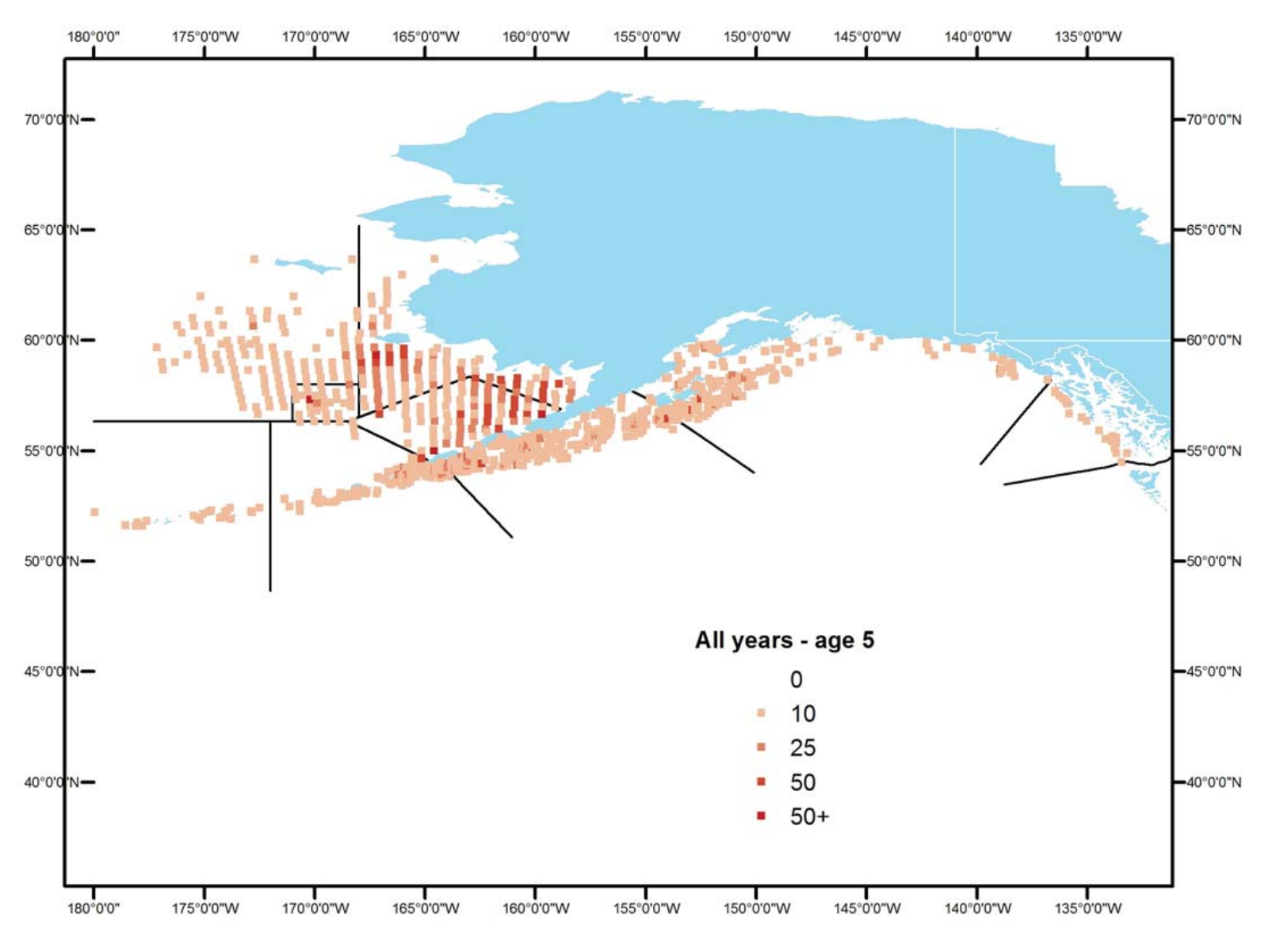
The temporal gap between that first glimpse of the population at 2 years old during the trawl survey, and recruitment into the commercial fishery is generally 6-10 years. Both year-class abundance and distribution can change substantially during that time. Young halibut face a number of challenges including varying food supply, favorable or unfavorable environmental conditions, predation, and disease.

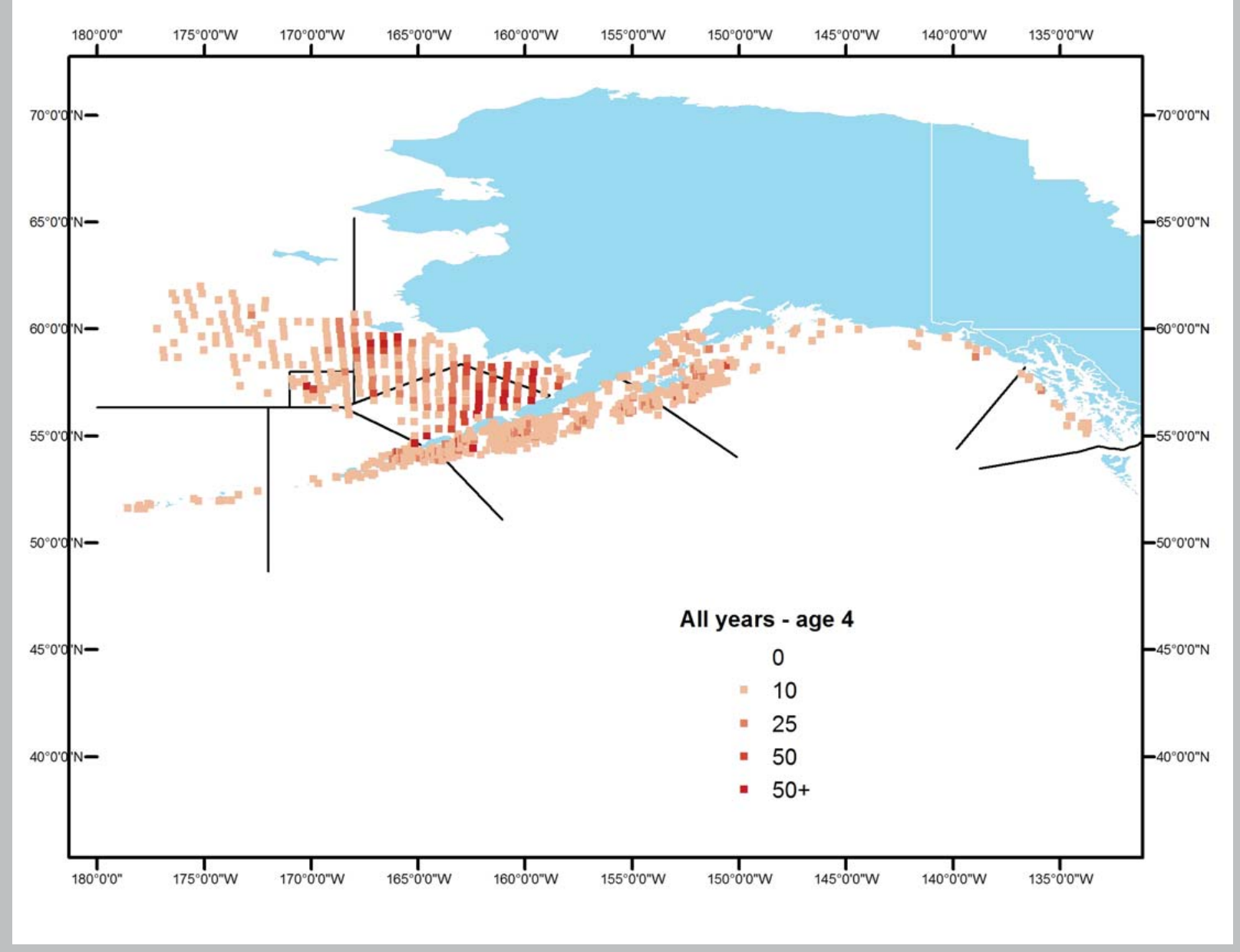
Figure 1

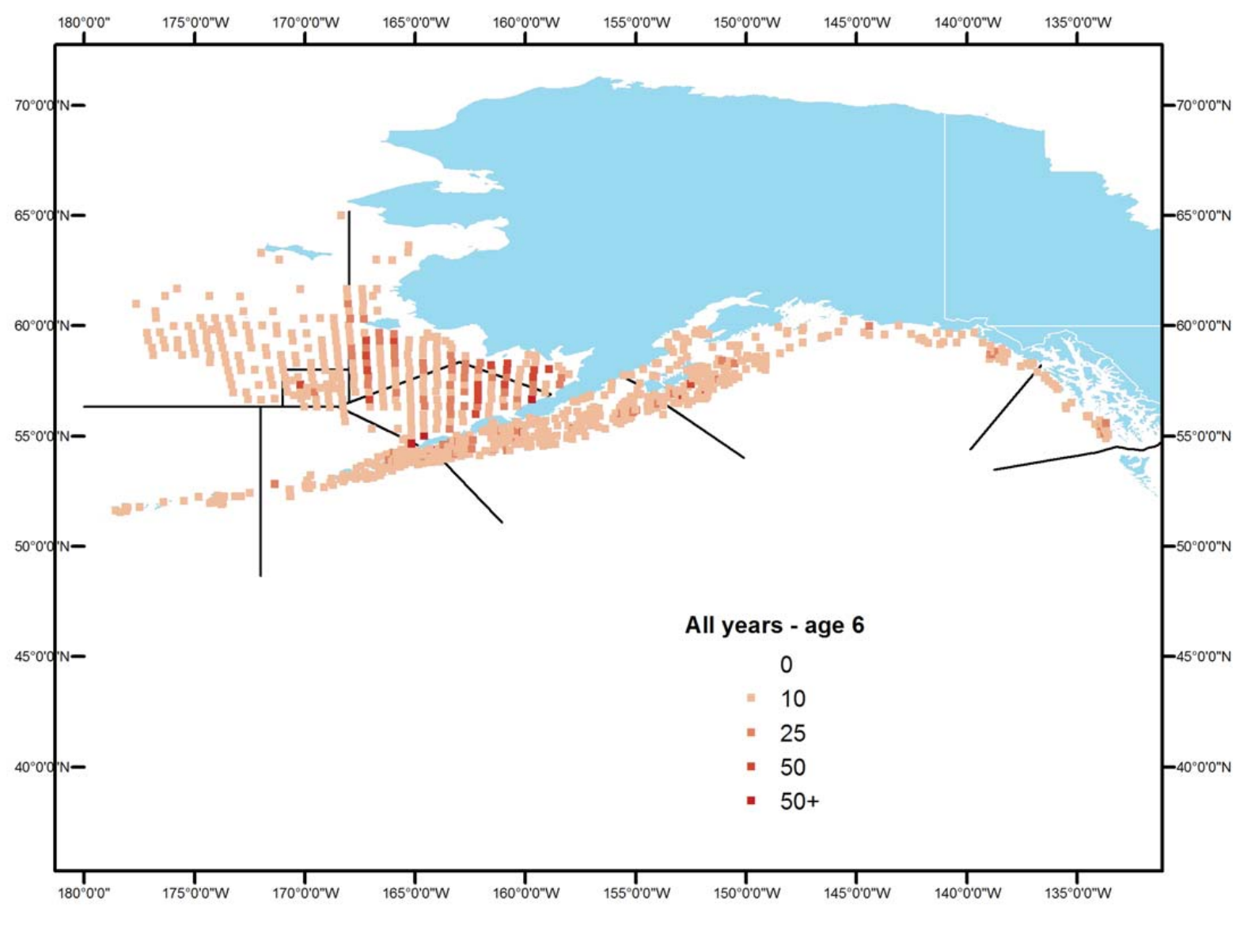












Distribution

Adult halibut migrate to the continental shelf edge in winter (November through March) to spawn. Major spawning grounds are thought to be concentrated in the central and western Gulf of Alaska (GOA) and the southern Bering Sea shelf edge. Eggs are laid in deep water along the slope and are then left to drift in the ocean currents as they mature through the hatching and larval phases.

Generally speaking, the prevailing currents transport the eggs and larvae from the spawning grounds westward in the GOA and northward in the Bering Sea (Fig. 1). Larvae also depend on currents to transport them to areas of plankton production and eventually inshore for settlement to the bottom in shallow nursery areas. It takes an estimated six months for a halibut to move from the egg phase to settlement in shallow coastal nursery areas where they have taken on the adult form (IPHC 2014).

Halibut begin a countermigration away from the nursery areas within a year or two of settlement and disperse eastward in the GOA and both westward and southward in the Bering Sea. The adjacent figures show the distribution of halibut at ages 2-6 for all years combined.

Environment and halibut abundance

Environment has been shown to play a critical role in the population variability of many marine species. Bakun (2010) described three classes of environmental conditions that combine to yield favorable habitat for reproduction and juvenile survival including: enrichment processes, frontal formation, and water column stability. In an effort to describe various environmental scenarios and monitor those scenarios through time, researchers have developed a suite of environmental indices, with each one including a unique set of parameters to describe particular climatic regimes or conditions.

Methods

The table below describes a number of environmental indices that were developed for the north Pacific and Bering Sea and that were used here in a principal component analysis (PCA) looking at environment in relation to year. The PCA was performed for each region using five indices for the GOA and seven for the Bering Sea, and included the years 1984-2013 and 1982-2013, respectively.

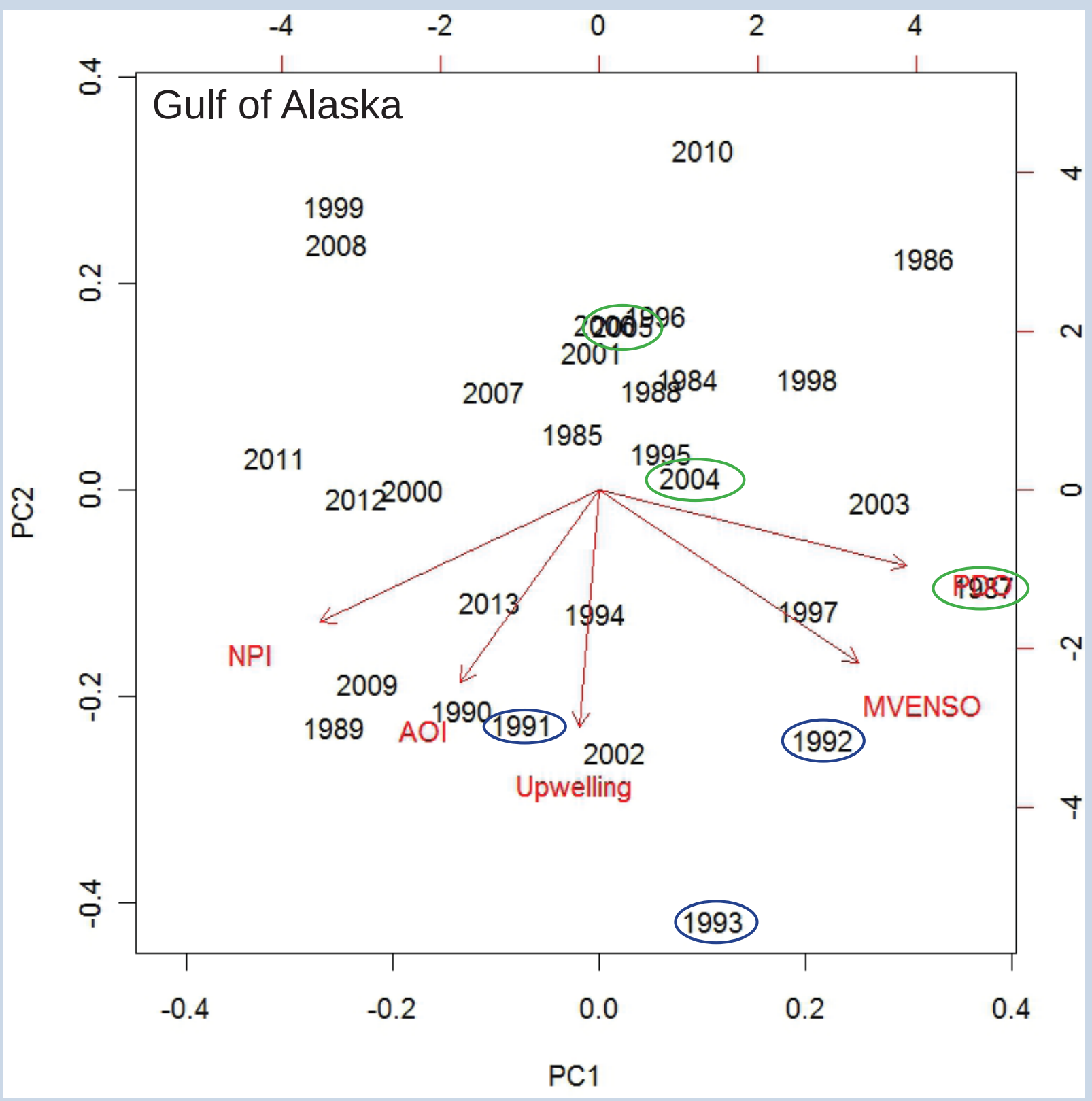
Index		**Description**
Pacific Decadal Oscillation[1]	PDO	Temperature-related environmental fluctuation on a decadal scale.
North Pacific Index[1,2]	NPI	A descriptor for atmospheric circulation over the central and western GOA and Bering Sea that corresponds to tendancies for stormy weather versus calm, warm weather.
El Nino Southern Oscillation[1]	MVENSO	One of several indices describing the effects of El Nino. During El Nino temperatures in the north tend to be warmer. The opposite is true during La Nina years.
Oceanic Nino Index[3]	ONI	One of several indices describing the effects of El Nino.
Arctic Oscillation Index[1]	AOI	The Arctic Oscillation is the dominant pattern of non-seasonal sea-level pressure (SLP) variations north of 20°N. When the AOI is positive, there tends to be colder temperatures in the north.
Bering Sea pressure index[1]	BSPIw	A measure of cyclonic activity linked with the strength of the Aleutian low. When the BSPIw is positive surface air temperatures tend to be colder than normal and vice versa.
Ice cover index[1]	ICI	A descriptor for the extent of sea ice cover in the Bering Sea.
BS Sea surface temperature[1]	SST_May	Sea surface temperatures in May, when ice has retreated from the southeastern Bering Sea.
BS bottom temperature[1]	BT	Indicates the intensity of the cold pool that persists through the summer.
Upwelling index[4]	Upwelling	Upwelled water originates from depths of 100 m or more, is cooler and saltier than the original surface water, and typically has much greater concentrations of nutrients. Upwelling values used here are from 60°N and 149°W.

[1] http://www.beringclimate.noaa.gov/data

[2] https://climatedataguide.ucar.edu/climate-data/north-pacific-np-index-trenberth-and-hurrell-monthly-and-winter

[3] http://www.esrl.noaa.gov/psd/data/climateindices/list/

[4] http://www.pfeg.noaa.gov/products/PFEL/modeled/indices/upwelling/NA/upwell_menu_NA.html

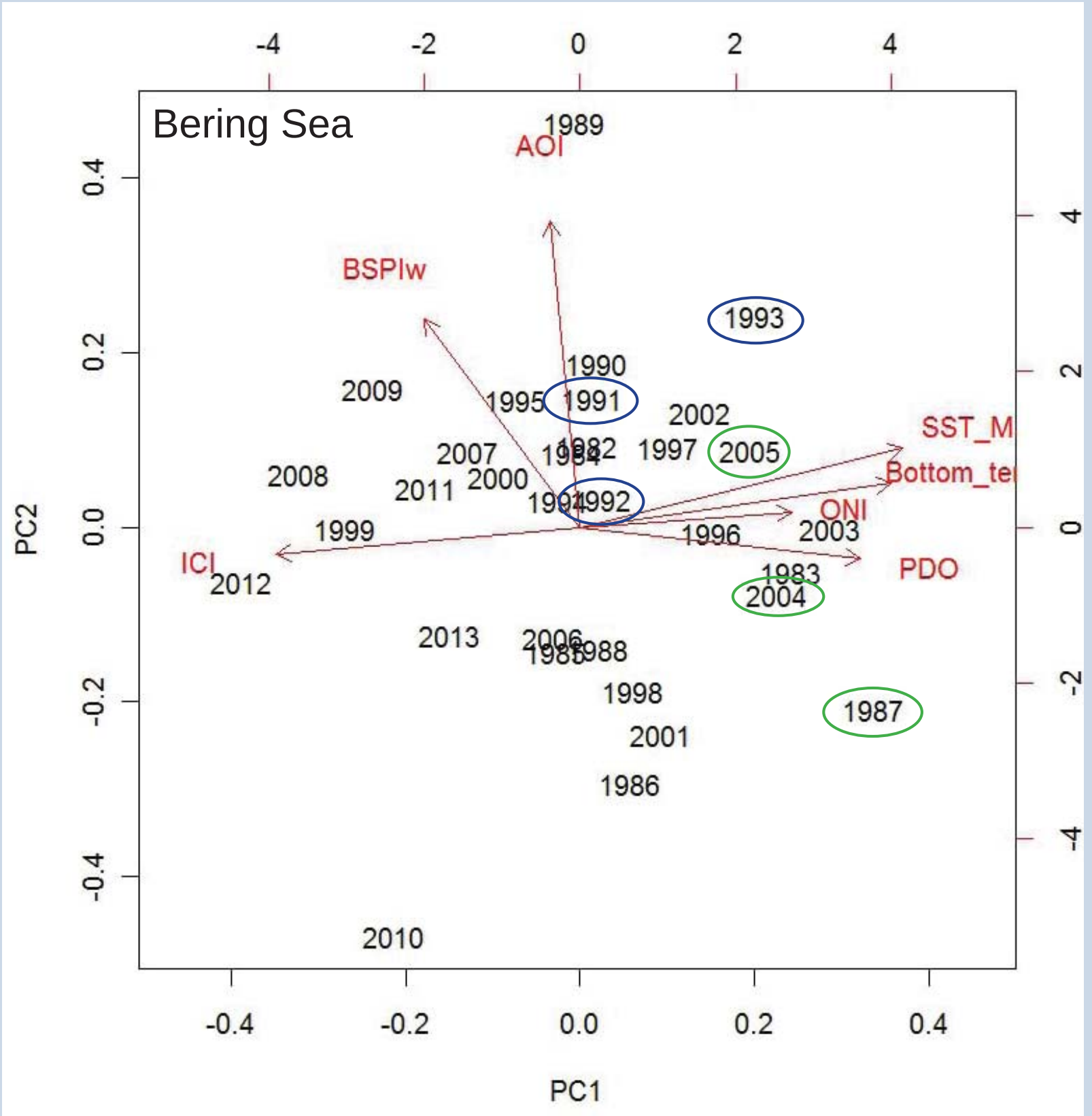


Gulf of Alaska PCA results					
	PC1	PC2	PC3	PC4	PC5
Standard deviation	1.4671	1.1003	0.9843	0.6659	0.4741
Proportion of variance	0.4305	0.2421	0.1938	0.0887	0.0450
Cumulative proportion	0.4305	0.6726	0.8664	0.9551	1

Results

Biplots (the figures to the right) of the first two principal components (PCs) in relation to year provides some context for conditions in a particular year. In both areas, the first two PCs have noticeable differences with primarily temperature-related indices on PC1 and pressure-related indices on PC2. Pressure can indicate temperature variations, but also advection and mixing processes.

Examining the placement of those years on the biplots which correspond to larger year-classes of halibut, (e.g. 1987 which is a confirmed large year class and 2004-2005, which appear large in the Bering Sea trawl survey and inconclusive in the GOA survey - years circled in green in both figures) shows that they were all years of positive temperature-related anomalies, or warmer years. Other years where recruitment has been determined to be poor, e.g. 1991, 1992, and 1993 (circled in blue), are placed neutral or positive on PC1. Those same years are positive on PC2 for the Bering Sea and negative for the GOA. The positive and negative loadings, respectively, in this case both indicate low pressure phases in Alaska, or more simply put, stormy, wet weather in Alaskan waters. Stormy weather means increased mixing in the water column, which likely interferes with transport of larvae to the surface and inshore.



Bering Sea PCA results							
	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Standard deviation	1.891	1.0905	0.9605	0.81507	0.56925	0.49061	0.28885
Proportion of variance	0.5108	0.1699	0.1318	0.09491	0.04629	0.03439	0.01192
Cumulative proportion	0.5108	0.6807	0.8125	0.9074	0.9537	0.98808	1

Discussion

Where halibut are concerned, both temperature-related and pressure-related processes likely impact the organisms the greatest at larval phases, when they are particularly vulnerable to environmental conditions. This is in contrast to juvenile halibut that have made it past the larval stages and settled to the bottom. Still, while years that produced particularly large or small year classes of halibut corresponded relatively well to environmental indices in this analysis, there are many years, some of them corresponding to larger than average halibut recruitment or smaller than average halibut recruitment, that were not clearly defined by particular environmental conditions. Likewise, there were years that, according to the environmental analysis alone, should have yielded larger or smaller year classes of halibut, but did not. Therefore, it is clear that while temperature and transport processes play a role in defining particularly large or small year classes, recruitment is a complex process involving a variety of factors, some of which challenge juvenile halibut after settlement. Such factors may include availability of prey, degree of predation, and environmental factors such as ocean acidification, hypoxia, and temperature fluctuations.

References

Bakun, A. 2010. Linking climate to population variability in marine ecosystems characterized by non-simple dynamics: Conceptual templates and schematic constructs. J. Mar. Sci. 79: 361-373.
International Pacific Halibut Commission. 2014. The Pacific halibut: biology, fishery, and management. Int. Pac. Halibut Comm. Tech Rep. 59. 60 p.
Stewart, I. J. and Martell, S. 2014. Assessment of the Pacific halibut stock at the end of 2013. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2013: 169-196.

Acknowledgements

Thank you to Paul Logan and Guy Becken for photos, and Ray Webster for statistical assistance.