135-year time series of Atlantic Puffin production is negatively correlated to sea surface temperature:

Population control by temperature dependent survival of ectotherm sandeel prey?

Erpur Snær Hansen et alia
Collaborative project

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The Westman 1880-2018 Puffin harvest series

Public records
Hx1.465 ±0.010 SE
Elliðaey n=37

Álsey record
H = H_{Álsey} / P_{Álsey >1968}
P_A = 0.161
±0.0096 SE
n=40

Feather Export (20 birds/#)

10 Private records
Missing values
TRIM v.3.51
CPUE explains \((R^2)\) 44% of the harvest variation \((r = 0.66)\)

\[
y = 182.55x + 1605.5
\]

\[R^2 = 0.4404\]
Icelandic seabird harvest 1898-2013

Normalized harvest

Year

Normalized harvest


-2 -1 0 1 2 3

F. arctica Westmans
F. arctica Iceland
Uria & Alca
R. tridactyla
L. fucus
P. aristotelis
A. torda
U. aalge
U. lomvia
F. glacialis
Age distribution of 4340 recaptures from harvesting 22 cohorts (1961-1982), each hunted ≥25 years

Age of maturity
Harvest & chick production index
(black, with grey 95% C.I.)

Year:
1880 1900 1920 1940 1960 1980 2000

Y-axis:
Puffin harvest [1,000 birds]

X-axis:
Chick production index
Sea Surface Temperature (SST) in Westmans

Summer, annual mean, & winter
Chick production (black), annual mean SST, & their correlation (with 95% C.I.). Correlations are estimated from 31-year sliding windows.
Chick production is affected by an interaction between summer & winter SST. High winter SST is always negatively related to production. High summer SST is negatively related to production only when winters are warm.
11-year trends in chick production (black) & annual mean SST

$r = +0.629$
$p = 0.006$

$r = -0.881$
$p < 0.001$

$r = +0.720$
$p = 0.004$
Sandeel length threshold ($L_{th}$) for wintering

Fish metabolic rate are proportional to size and increase with temperature which together determine a threshold for wintering, but fish under the threshold experience reduced survival without feeding.

van Deurs, Hartvig & Steffensen (2011)

Annual $L_{th}$ is calculated for August-April 1880-2014.
Sandeel proportion $<L_{th}>$ warm & cold periods

Z = 4.27697, P<0.00002
Conclusions

• Hunting effort stable from 1880, biological signal real.

• Key demographic: Productivity, highly variable.

• Productivity is highly SST dependent with a seasonal interaction.

• Puffin SST dependence possibly connected to sandeel ecophysiology.
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Correlation btw harvest & summer SST: $r = -0.27$ (N.S., $N^* = 16$).
Correlation btw harvest & winter SST: $r = -0.51$ (P<0.05, N* = 16).
Correlation btw harvest & $L_{th}$: 
$r = -0.47$ (P<0.05, N*=16).
Winter & summer SST vs harvest

SST May-July (°C)

Harvest (x1000 individuals)

Year


1892 1932 1968 1990 2005


SST May-July (°C)

Harvest (x1000 individuals)