Supplementary information

Marine heatwaves are not a dominant driver of change in demersal fishes

In the format provided by the authors and unedited

Supplementary Table 1: Survey names and sample sizes used in the main analysis, and corresponding abbreviations used in figures and tables. The survey codes from FISHGLOB are also listed for comparison to other data from the FISHGLOB Consortium.

FISHGLOB Code	Survey	Number of Survey-Years	Abbreviation
BITS	Baltic Sea	19	BalS
DFO-QCS	British Columbia	10	BC
EBS	Eastern Bering Sea	26	EBS
EVHOE	France	22	FR
FR-CGFS	English Channel	22	EC
GMEX	Gulf of Mexico	26	GoM
GOA	Gulf of Alaska	11	GoA
GSL-S	Gulf of Saint Lawrence	25	GSL
IE-IGFS	Ireland	17	IR
NEUS	Northeast US	26	NeUS
NIGFS	Northern Ireland	11	NI
Nor-BTS	Barents Sea	24	BarS
NS-IBTS	North Sea	26	NS
PT-IBTS	Portugal	12	PO
SCS	Scotian Shelf	24	SS
SEUS	Southeast US	26	SeUS
SWC-IBTS	Scotland	26	SC
WCANN	West Coast US	16	WUS

Supplementary Table 2: Models of biomass log ratio (LR) response to MHW cumulative intensity in °C-days (MHW CInt). MHW CInt was calculated from the detrended GLORYS sea bottom temperature data with a five-day minimum duration threshold for MHWs, as used in the main text. Model names correspond to: null (intercept-only) model, linear model, linear model including survey as a fixed effect, generalized additive model (GAM), and GAM including survey as a random effect. * denotes variables that were scaled and centered within surveys and s() denotes a GAM smoother.

	Null	LM	LM Survey	GAM	GAM Survey
Model formula	Biomass LR* ∼ 1	Biomass LR* ∼ MHW CInt*	Biomass LR* ∼ MHW CInt* + Survey[fixed]	Biomass LR* ∼ s(MHW CInt*)	Biomass LR* ∼ s(MHW CInt*) + Survey[random]
Intercept	0.00 ± 0.051	0.00 ± 0.052	0.00 ± 0.236	0.00 ± 0.051	0.00 ± 0.051
MHW coefficient	NA	0.008 ± 0.053	0.008 ± 02	NA	NA
Coefficient p-value	NA	0.88	0.883	0.593	0.593
R^2	0.000	0.000	0.000	0.004	0.004
AIC	1007	1009	1043	1009	1009
Degrees of freedom	359	358	341	356	356

Supplementary Table 3: Linear models of biomass log ratio (LR) response to MHW cumulative intensity in °C-days (MHW CInt) in each individual region (model formula: Biomass LR* ~ MHW CInt*, where * denotes variables that were scaled and centered within surveys). MHW CInt was calculated from the detrended GLORYS sea bottom temperature data with a five-day minimum duration threshold for MHWs, as used in the main text.

	Intercept	MHW coefficient	Coefficient p-value	R^2	AIC	Degrees of freedom
Baltic Sea	0.00 ± 0.243	-0.012 ± 0.25	0.962	0.00	56	16
British Columbia	0.00 ± 0.338	0.316 ± 0.359	0.408	0.10	30	7
Eastern Bering Sea	0.00 ± 0.187	-0.358 ± 0.191	0.073	0.128	75	24
France	0.00 ± 0.221	0.164 ± 0.226	0.478	0.027	64	19
English Channel	0.00 ± 0.221	0.15 ± 0.227	0.516	0.022	64	19
Gulf of Mexico	0.00 ± 0.192	-0.287 ± 0.196	0.155	0.082	77	24
Gulf of Alaska	0.00 ± 0.283	-0.535 ± 0.299	0.111	0.286	30	8
Gulf of Saint Lawrence	0.00 ± 0.193	0.332 ± 0.197	0.105	0.11	73	23
Ireland	0.00 ± 0.258	-0.059 ± 0.267	0.828	0.003	50	14
Northeast US	0.00 ± 0.187	0.352 ± 0.191	0.078	0.124	75	24
Northern Ireland	0.00 ± 0.335	-0.02 ± 0.353	0.957	0.00	33	8
Barents Sea	0.00 ± 0.209	0.015 ± 0.213	0.944	0.00	73	22
North Sea	0.00 ± 0.20	-0.066 ± 0.204	0.75	0.004	79	24
Portugal	0.00 ± 0.299	-0.342 ± 0.313	0.303	0.117	35	9
Scotian Shelf	0.00 ± 0.209	0.009 ± 0.213	0.968	0.00	73	22
Southeast US	0.00 ± 0.20	-0.011 ± 0.204	0.956	0.00	79	24
Scotland	0.00 ± 0.20	0.076 ± 0.204	0.712	0.006	79	24
West Coast US	0.00 ± 0.264	0.163 ± 0.274	0.562	0.027	47	13

Supplementary Table 4: Models of absolute biomass log ratio (LR) response to MHW cumulative intensity in °C-days (MHW CInt). MHW CInt was calculated from the detrended GLORYS sea bottom temperature data with a five-day minimum duration threshold for MHWs, as used in the main text. Model names correspond to: null (intercept-only) model, linear model, linear model including survey as a fixed effect, generalized additive model (GAM), and GAM including survey as a random effect. * denotes variables that were scaled and centered within surveys and s() denotes a GAM smoother.

	Null	LM	LM Survey	GAM	GAM Survey
Model formula	Absolute Biomass LR* ~ 1	Absolute Biomass LR* ~ MHW CInt*	Absolute Biomass LR* ~ MHW CInt* + Survey[fixed]	Absolute Biomass LR* ~ s(MHW CInt*)	Absolute Biomass LR* ~ s(MHW CInt*) + Survey[random]
Intercept	0.771 ± 0.031	0.771 ± 0.031	0.762 ± 0.143	0.771 ± 0.031	0.771 ± 0.031
MHW coefficient	NA	0.041 ± 0.032	0.041 ± 02	NA	NA
Coefficient p-value	NA	0.209	0.219	0.236	0.236
R^2	0.000	0.004	0.011	0.002	0.002
AIC	653	653	685	653	653
Degrees of freedom	359	358	341	358	358

Supplementary Table 5: Models of biomass log ratio (LR) response to MHW cumulative intensity in °C-days (MHW CInt). MHW CInt was calculated from the detrended GLORYS sea bottom temperature data with a five-day minimum duration threshold for MHWs, as used in the main text. Model names correspond to: null (intercept-only) model, linear model, linear model including survey as a fixed effect, generalized additive model (GAM), and GAM including survey as a random effect. * denotes variables that were scaled and centered within surveys, ** denotes variables that were scaled and centered across surveys, and s() denotes a GAM smoother. This table is identical to Supp. Tab. 2, except rather than centering and scaling MHW CInt within regions, it is centered and scaled across regions. The approach used in most of our analysis (centering and scaling MHW CInt within regions) assumes that history matters in ecological responses to MHW responses, i.e., that biomass change should be compared to how anomalous a MHW is relative to other MHWs that occurred in the region. Here, we test the hypothesis that absolute MHW CInt matters regardless of the oceanographic history of each region by centering and scaling MHW CInt across regions.

	Null	LM	LM Survey	GAM	GAM Survey
Model formula	Biomass LR* $\sim$ 1	Biomass LR* $\sim$ MHW CInt**	Biomass LR* $\sim$ MHW CInt** + Survey[fixed]	Biomass LR* $\sim$ s(MHW CInt**)	Biomass LR* $\sim$ s(MHW CInt**) + Survey[random]
Intercept	0.00 ± 0.051	0.00 ± 0.052	0.002 ± 0.236	0.00 ± 0.051	0.00 ± 0.051
MHW coefficient	NA	0.009 ± 0.052	0.009 ± 02	NA	NA
Coefficient p-value	NA	0.867	0.865	0.185	0.18
R^2	0.000	0.000	0.000	0.019	0.019
AIC	1007	1009	1043	1008	1008
Degrees of freedom	359	358	341	352	352

Supplementary Table 6: Models of biomass log ratio (LR) response to lagged MHW cumulative intensity in °C-days (MHW CInt). MHW CInt was calculated from the detrended GLORYS sea bottom temperature data with a five-day minimum duration threshold for MHWs, as used in the main text. These are generalized additive models (GAMs) that use a smoothed predictor matrix containing lagged MHW data for up to five years into the past. Results from the GAM for 0-1 years in the past, i.e., the twelve months preceding a survey, can be found in Supp. Tab. 2. * denotes variables that were scaled and centered within surveys and s() denotes a GAM smoother.

	1-2 Years	1-3 Years	1-4 Years	1-5 Years
Model formula	Biomass LR* $\sim$ s(matrix(MHW CInt*[lag1:2]))	Biomass LR* $\sim$ s(matrix(MHW CInt*[lag1:3]))	Biomass LR* $\sim$ s(matrix(MHW CInt*[lag1:4]))	Biomass LR* $\sim$ s(matrix(MHW CInt*[lag1:5]))
p-value	0.531	0.552	0.164	0.559
R^2	-0.002	0.001	0.003	-0.002
AIC	955	902	841	797
Degrees of freedom	340	321	304	286

Supplementary Table 7: Null (intercept-only) model and generalized linear model (GLM) of biomass log ratio (LR) as a function of MHW cumulative intensity in °C-days (MHW CInt) and biomass from the previous time step. * denotes variables that were scaled and centered within surveys and : denotes an interaction term between two variables. This Gompertz model accounts for autoregressive properties of the biomass time-series and tests whether the magnitude of biomass in any given year affected the biomass LR in the following year. MHW Cint was calculated from the detrended GLORYS sea bottom temperature data with a five-day minimum duration threshold for MHWs, as used in the main text. Rather than centering and scaling biomass variables, to account for variability and heteroskedasticity among surveys, we included survey identity as a fixed effect and allowed dispersion to vary among surveys.

	Null model	Gompertz GLM
Model formula	Biomass LR $\sim$ 1	Biomass LR $\sim$ MHW CInt* + Lag(Log Biomass) + Survey + MHW CInt*:Survey
Intercept	0.01 ± 0.013	0.317 ± 0.241
MHW coefficient	NA	-0.009 ± 0.012
Coefficient p-value	NA	0.444
R^2	0.00	0.335
AIC	180	99
Degrees of freedom	341	287

Supplementary Table 8: Models of biomass log ratio (LR) response to latitude only (null model) or MHW cumulative intensity in °C-days (MHW CInt) and latitude. Latitude was calculated as the median latitude of each survey. * denotes variables that were scaled and centered within surveys, ** denotes variables that were scaled and centered across surveys, and : denotes an interaction term between two variables. MHW CInt was calculated from the detrended GLORYS sea bottom temperature data with a five-day minimum duration threshold for MHWs, as used in the main text.

	Null model	Linear model
Model formula	Biomass LR* ~ Latitude**	Biomass LR* ~ Latitude** + MHW CInt* + Latitude**:MHW CInt*
Intercept	0.00 ± 0.052	0.00 ± 0.052
MHW coefficient	NA	0.008 ± 0.053
Latitude coefficient	0.00 ± 0.052	0.00 ± 0.052
Interaction coefficient	NA	-0.006 ± 0.053
MHW coefficient p-value	NA	0.88
Latitude p-value	1.00	1.00
Interaction p-value	NA	0.909
R^2	0.00	0.00
AIC	1009	1013
Degrees of freedom	358	356

Supplementary Table 9: Null (intercept-only) model and model of depth response to MHW cumulative intensity in °C-days (MHW CInt). Depth was calculated as the weighted mean depth of the fish assemblage every year. * denotes variables that were scaled and centered within surveys. We calculated MHW CInt from the detrended GLORYS sea bottom temperature data with a five-day minimum duration threshold for MHWs, as used in the main text.

	Null model	Linear model
Model formula	Depth* ~ 1	Depth* ~ MHW CInt*
Intercept	0.00 ± 0.053	0.00 ± 0.053
MHW coefficient	NA	-0.016 ± 0.055
Coefficient p-value	NA	0.775
R^2	0.00	0.00
AIC	937	939
Degrees of freedom	334	333

Supplementary Table 10: Models of biomass log ratio (LR) response to catch only (null model) or MHW cumulative intensity in °C-days (MHW CInt) and catch. We matched survey footprints to Marine Ecoregions (MEs) and extracted catch data from the Sea Around Us database (see Methods). Surveys from the English Channel and France did not correspond well to ME boundaries and were omitted. Because catch was available by calendar year and surveys occur midyear, we compared biomass change to the mean of the last three years of catch (i.e., biomass change in a 2010 survey was predicted by mean catch in 2008, 2009, and 2010). * denotes variables that were scaled and centered within surveys and : denotes an interaction term between two variables. MHW CInt was calculated from the detrended GLORYS sea bottom temperature data with a five-day minimum duration threshold for MHWs, as used in the main text.

	Null model	Linear model
Model formula	Biomass LR* ~ Catch*	Biomass LR* ~ MHW CInt* + Catch* + MHW CInt*:Catch*
Intercept	-0.018 ± 0.056	-0.019 ± 0.056
MHW coefficient	NA	-0.02 ± 0.057
Catch coefficient	-0.039 ± 0.061	-0.041 ± 0.061
Interaction coefficient	NA	-0.04 ± 0.063
MHW coefficient p-value	NA	0.732
Catch coefficient p-value	0.527	0.503
Interaction p-value	NA	0.528
R^2	0.001	0.003
AIC	864	868
Degrees of freedom	309	307

Supplementary Table 11: Models of Community Temperature Index change (measured as year-over-year difference values, CTI Diff) and MHW cumulative intensity in °C-days (MHW CInt). * denotes variables that were scaled and centered within surveys and s() denotes a GAM smoother. MHW CInt was calculated from the detrended GLORYS sea bottom temperature data with a five-day minimum duration threshold for MHWs, as used in the main text. Model names correspond to: null (intercept-only) model, linear model, linear model including survey as a fixed effect, generalized additive model (GAM), and GAM including survey as a random effect.

	Null	LM	LM Survey	GAM	GAM Survey
Model formula	CTI Diff* $\sim$ 1	CTI Diff* $\sim$ MHW CInt*	CTI Diff* $\sim$ MHW CInt* + Survey[fixed]	CTI Diff* $\sim$ s(MHW CInt*)	CTI Diff* $\sim$ s(MHW CInt*) + Survey[random]
Intercept	0.00 ± 0.051	0.00 ± 0.051	0.00 ± 0.236	0.00 ± 0.051	0.00 ± 0.051
MHW coefficient	NA	0.051 ± 0.053	0.051 ± 02	NA	NA
Coefficient p-value	NA	0.332	0.344	0.311	0.311
R^2	0.000	0.003	0.003	0.004	0.004
AIC	1007.170	1008.223	1042.223	1007.244	1007.244
Degrees of freedom	359.000	358.000	341.000	357.311	357.311