LETTER

Environment drives forage fish productivity

Understanding the interaction between fishing and natural variations in productivity is a central question in fisheries management. Essington et al. (1) advance the discussion on drivers of forage fish dynamics by highlighting the role of natural decreases in biomass collapses. A key conclusion of their work is that fishing increases the magnitude and frequency of collapse in biomass. More intense fishing necessarily results in fewer fish; however, the higher exploitation rates commonly seen as forage fish biomass declines do not always mean that fishing precipitated collapses in productivity.

Using a biomass threshold to identify when collapses occur might be appropriate if biomass were the key driver of productivity (i.e., a stock–recruitment relationship exists). However, this is untrue for 88% of the stocks in Essington et al. (1) (demonstrated in ref. 2), a point that the authors make. So, changes in recruitment must be compared with exploitation patterns to explore the influence of fishing on productivity. To achieve this, we applied a break-point algorithm (3) to the time series' of recruitment for the stocks in Essington et al. (1) to identify periods of lower productivity (see Fig. 1 for examples). Recruitment for 23 stocks shifted to low productivity at some point in their history and only one of those stocks appeared to have a repeatable stock–recruit relationship. The median relative exploitation pressure for these stocks before a shift in productivity was significantly less than exploitation pressure after (Fig. 1, *Left*; $P < 0.05$), suggesting that high exploitation does not precipitate collapse in recruitment. The relative exploitation rate before a collapse in recruitment was not significantly related to the magnitude of the collapse. Furthermore, recovery (e.g., North Sea herring in Fig. 1) was generally not preceded by increasing biomass or decreased exploitation; biomass increased and exploitation decreased only after recruitment increased again (Fig. 1, *Right*). These observations suggest that fishing plays little role in the dynamics of forage fish productivity.

Essington et al. (1) point out a pattern in biomass collapses: high exploitation rates, drops in productivity, and lagged responses to reducing fishing effort. However, the actual sequence of events often begins with a collapse in recruitment followed by biomass declines. Catches also begin to decline (but more slowly than biomass), thus exploitation rates rise. Eventually biomass reaches a "collapsed" level and, because of the increased exploitation rates, fishing appears to have precipitated the collapse, even though the process started with recruitment.

The metric chosen to represent collapse can influence the inferred timing and magnitude of collapse, in addition to engendering different perspectives in management on the role of fishing in collapses of stocks. Decreases in biomass following recruitment collapses do not always register as a collapse in biomass [e.g., Herring ICES (International Council for the Exploration of the Sea) VIIa–g–h–j; Fig. 1]. Similarly, collapses in biomass are not always accompanied by collapses in recruitment (e.g., Sandeel North Sea Area 1; Fig. 1). Management should respond to collapses in recruitment by endeavoring to prevent fishing mortality from rising as biomass declines, rather than waiting for biomass to decline and then reacting.

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1 Essington TE, et al. (2015) Fishing amplifies forage fish population collapses. *Proc Natl Acad Sci USA* 112(21):6648–6652.

2 Szuwalski CS, Vert-Pre K, Punt AE, Branch TA, Hilborn R (2014) Examining common assumptions about recruitment: A meta-analysis of global recruitment dynamics. *Fish Fish*, 10.1111/faf.12083.

3 Rodionov S (2004) A sequential algorithm for testing climate regime shifts. *Geo Res Lett* 31(9):L09204.

Author contributions: C.S.S. and R.H. designed research, performed research, analyzed data, and wrote the paper.

The authors declare no conflict of interest.

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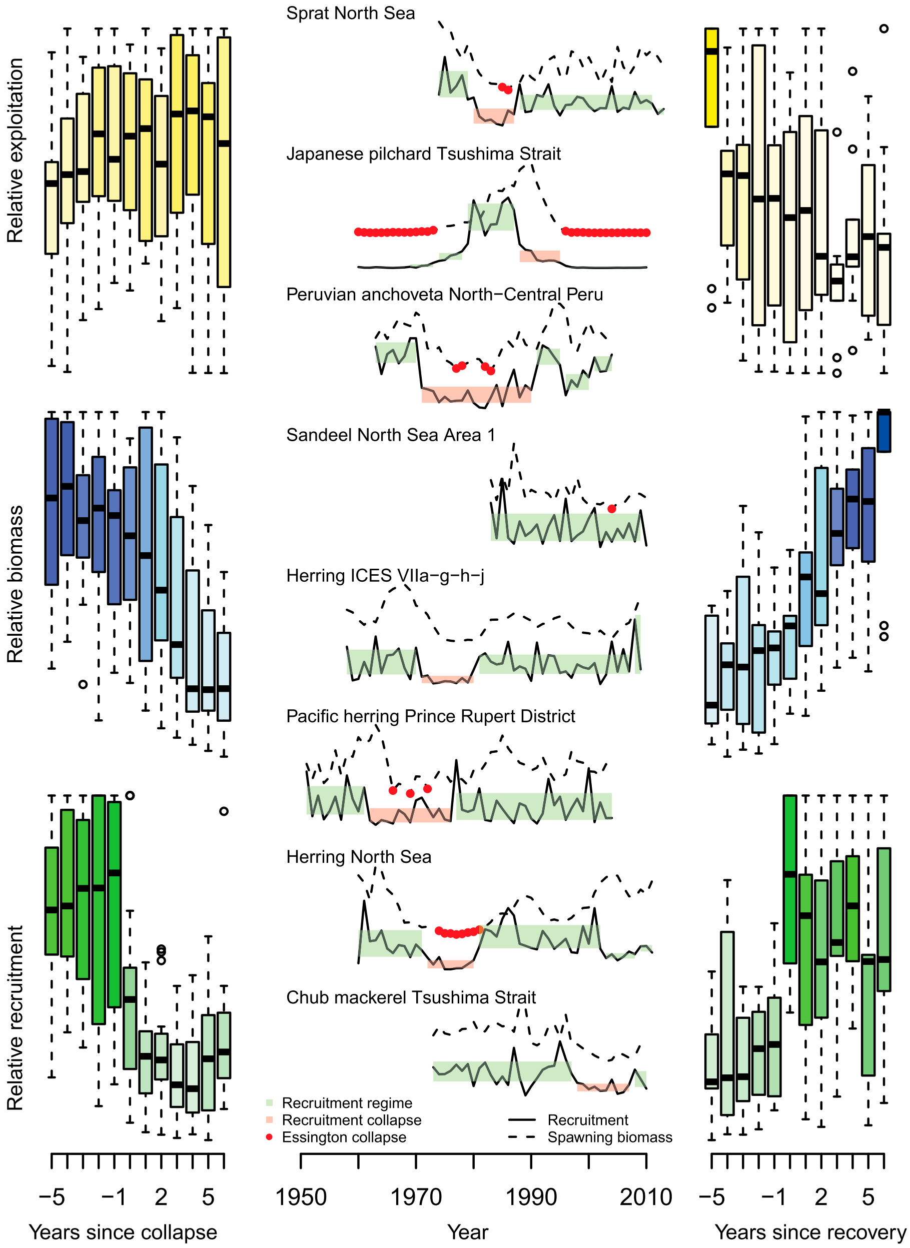

Fig. 1. Relationship between scaled recruitment, spawning biomass, and relative exploitation around collapses (*Left*) and recoveries (*Right*) in recruitment and time series of recruitment and biomass for selected stocks (*Center*). Colored boxes around recruitment time series indicate “regimes” selected by a break-point algorithm.