California swordfish fishery: Maximizing the catch rate of a target species simultaneously minimizes bycatch rates

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Marine megafauna represent a key component of ocean condition and functioning. However, these species are becoming increasingly threatened by incidental capture in nontarget fisheries as bycatch. Although several studies have investigated spatial and temporal hotspots for bycatch, few have examined the fundamental physical drivers that underlie observed patterns. In PNAS, Scales et al. (1) address this gap by identifying high-resolution Lagrangian coherent structures (LCS) in ocean surface velocity fields and by quantifying their influence on the likelihood of marine megafauna bycatch in a swordfish fishery operating within the California Current System. The sophisticated approach and the results presented by Scales et al. (1) expand our view of ecological processes governing fisheries interactions with nontarget species and suggest the possibility of a new form of fisheries mitigation.

Scales et al. (1) identify a pattern of increased catch densities of swordfish, as well as other economically valuable and vulnerable species, in association with attracting LCS—that is, areas with low backward-in-time Finite-Time Lyapunov Exponent ($FTLE_b$) values. Therefore, it might be tempting to suggest that simply relocating the fishery toward areas of higher $FTLE_b$ values could facilitate bycatch reduction in marine fisheries. However, catches of swordfish and bycatch species do not decline at the same rate in relation to increasing $FTLE_b$ values. Consequently, we examined whether there is a magnitude of this environmental descriptor that would optimize the trade-off between catching target versus nontarget species.

We extracted the mean and 95% confidence intervals associated with the reported catches of swordfish (figure 2B in ref. 1) and all bycatch species (figure 3B in ref. 1) across six values of $FTLE_b$: −2.5, −2.0, −1.5, −1.0, −0.5, and 0. We simulated a catch-per-trip dataset for each group of species by randomly sampling 1,000 values from normal distributions with log-transformed parameters derived from these reported 95% confidence intervals. We then compared 100 randomly selected values (back-transformed) from each simulated dataset to estimate a distribution for the number of bycatch caught per swordfish, across different levels of $FTLE_b$ (Fig. 1).

Based on the described simulation, it appears that relocating fishing vessels based solely on the magnitude of $FTLE_b$ may have unintended consequences. While it is true that areas of higher $FTLE_b$ have lower catch rates of bycatch species, the number of bycatch caught per swordfish could increase (Fig. 1). Thus, in a quota system that limits the number of swordfish per vessel, such a strategy would have the net effect of increasing total bycatch. This result supports Scales et al. (1) suggestion that multiple environmental variables are needed to distinguish the spatial niche of different species. The catch ratio of target to nontarget species may provide a useful additional measure for evaluating initiatives that aim to mitigate bycatch based on such environmental descriptors.

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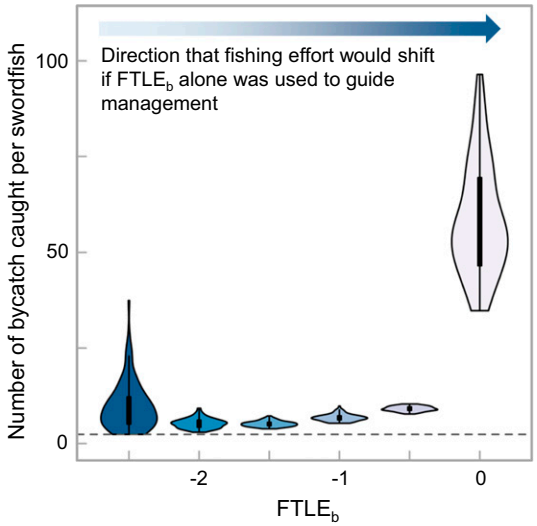

Fig. 1. Total number of bycatch caught per swordfish in a single fishing trip, examined at different levels of attracting LCS as ridges of the FTLE$_b$ field. Kernel density plots (with interior box plots) are colored in order of FTLE$_b$ magnitude. The horizontal gray dashed line demarks the lowest observed number of bycatch caught per swordfish.

1 Scales KL, et al. (2018) Fisheries bycatch risk to marine megafauna is intensified in Lagrangian coherent structures. *Proc Natl Acad Sci USA* 115:7362–7367.