Spatio-temporal Interactions Between Fish Spawning Aggregations, Fisheries, and Climate Change

Interacciones Espaciales y Temporales entre el Pescado que Engendra Agregaciones, Pesquerías, y Cambio Climático

Interactions Spatio-temporelle entre des Frayères de Poissons, la Pêche et le Changement Climatique

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EXTENDED ABSTRACT

Fish spawning aggregations (FSAs) are loosely defined as temporary, predictable, and repeatable gatherings of large numbers of conspecific fish that form for the purpose of reproduction (Domeier and Colin 1997). FSAs may represent the only times when fish reproduce and thus are critical for sustaining populations and species that engage in this behavior. FSAs also play key roles in ecosystem structure, health, and function while also supporting some of the most productive and important subsistence, recreational, and commercial fisheries worldwide (Erisman et al. 2015). While FSAs tend to be associated with groupers, snappers, and other tropical reef fish families, they are global in occurrence and form at a wide variety of habitats such as estuaries, seamounts, temperate rocky reefs, and river deltas (Russell et al. 2014). Despite their global relevance to ecosystems and fisheries, few FSAs have been assessed, many are declining or have disappeared, and only a small proportion of known FSAs are managed (Sadovy et al. 2008, Russell et al. 2014).

FSAs vary considerably with respect to their spatial and temporal dynamics, including the timing and duration of aggregations, the abundance and distribution of fish within aggregations, and the scale of migrations to reach aggregations. Such variations exist both among species and across different stocks and populations within a single species. Fishing activities are also highly variable with respect to the spatial and temporal distribution of effort, and the impacts of fishing on FSAs (e.g. reductions in reproductive output, population declines) are dictated by the interactions between fishing and spawning (Figure 1). Therefore, understanding the degree to which fishing interacts with aggregations and the spatio-temporal scale of these interactions are critical for stock assessments and the design of management policies of aggregating species (Sadovy de Mitcheson and Erisman 2012).

Traditional stock assessments tend to focus on mortality, population structure, growth, and fecundity to estimate the reproductive potential of a stock and often ignore aspects of spawning behavior. Several studies have shown that stock assessments of aggregating species that rely on estimates of reproductive potential are highly sensitive to age or size-dependent patterns in spawning frequency (Fitzhugh et al. 2012, Erisman et al. 2014). Therefore, age or density-related variations in spawning behavior may significantly influence the estimated vulnerability or resilience of a species to fishing pressure and the rate of recovery following protection. Such information is particularly important for instances in which fishing pressure is focused on the locations and periods when fish are aggregated and spawning and selects for the removal of larger individuals with higher reproductive potentials. Empirical and theoretical studies demonstrate that including detailed information on reproductive behavior can provide key insights on potential management strategies that improve stock resilience (via increases in reproductive output) while minimizing impacts on fisheries yields (Heppell et al. 2006, Erisman et al. 2012, Grüss and Robinson 2014).

Given the influence of water temperature on the timing of reproduction in marine fishes, global warming is likely to induce significant changes on the timing, duration, and locations of FSAs that may also alter their interactions with fisheries (Portner and Peck 2010, Poloczanska et al. 2013). For fishes that migrate to form spawning aggregations at specific times and locations, we see a similarity in the strength of the influence of temperature on spawning as shown by analyzing the mean temperature, the temperature range, and the relative temperature under which spawning occurs. These species have all evolved specific thermal ranges, which seem to be a product of both their environmental conditions and their evolutionary history. Therefore, changes in ocean temperatures are likely to cause changes in the spatio-temporal dynamics of spawning in aggregating species. For example, modeled scenarios for the Nassau Grouper (*Epinephelus striatus*) predict an overall decrease in spawning activity throughout its range, a shift in the spawning season, and a northward shift in the geographic range where peak spawning occurs. While these modeled scenarios are merely hypothetical, and more studies on localized adaptions of fish spawning to climate change are needed (Petitgas et al. 2013), these projections are a reminder of the potential effects of climate-induced changes on the productivity of stocks and the effectiveness of current management policies (e.g. spatial and seasonal closures) to reduce the impacts of fishing on FSAs.

KEY WORDS: Fish spawning aggregations, marine fisheries, stock assessments, climate change, spawning phenology

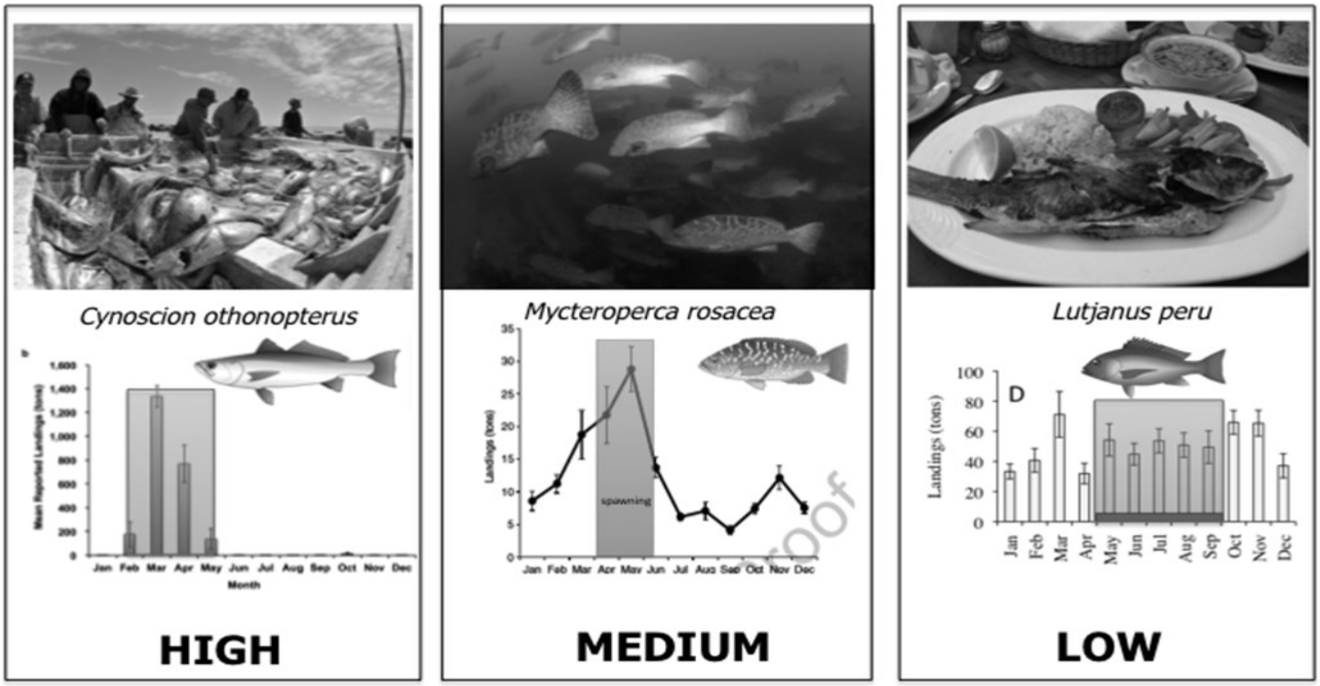

Figure 1. Variations in seasonal interactions between commercial landings and spawning aggregations in three species of commercial importance in the Gulf of California, Mexico. Photos (Left panel) Interactions between fishing and spawning in the Gulf Corvina (Cynoscion othonopterus) are extremely high, as nearly all fish are harvested from spawning aggregations. (Middle panel) Interactions between fishing and spawning in the Leopard Grouper (*Mycteroperca rosacea*) are moderate, as peak landings coincide with the spawning season but significant landings also occur during other months. (Right panel) Fishing activities for the Pacific Red Snapper (*Lutjanus peru*) occur year round and do not specifically target spawning aggregations but rather focus on juvenile and subadult fish. Shaded rectangles delineate the spawning season for each species. Data from Erisman et al. 2010 and Erisman et al. 2014. Photos by O. Aburto-Oropeza.

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