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Factors dampening population-level responses despite organismal ecotoxicity

summer of 2010 (Graham et al. 2010), and mesocosm trials indicate that phytoplankton taxa such as diatoms, euglenophytes, and chlorophytes may have increased in relative (if not total) abundance in oil-contaminated coastal waters (Gilde and Pinckney 2012). Changes in the assemblages of primary producers and zooplankton likely affected the survival of fish eggs and larvae through an impairment of resource acquisition (presumed negative effects) and avoidance of predators in the water column (presumed positive effects). Benthic infauna, including polychaetes, oligochaetes, and meiofauna, respond positively to oil enrichment, which, for many fishes, likely increases available prey resources (DeLaune et al. 1984, Brzorad and Burger 1994). However, it remains questionable whether benthic-feeding fishes forage effectively within contaminated sediments (Gregg et al. 1997). Within salt-marsh and seagrass ecosystems, shrimps, crabs, insects, and spiders are all highly sensitive to PAH toxicity and exhibited short-term decreases in densities following oiling, with recovery apparent by the summer of 2011 (McCall and Pennings 2012, Moody et al. 2013). Therefore, food sources for fishes—but also potential intraguild predators—were altered with latent cascading effects on the population ecology of fishes in oil-affected areas. At higher [illegible]

herring exemplify following the EV spill, populations can harbor instabilities over protracted periods that may eventually result in delayed collapses (Thorne and Thomas 2008). Fishery production in the GOM is tightly linked to coastal vegetated habitats that serve as spawning habitat, foraging areas, or nursery grounds (Peterson and Turner 1994). Salt-marsh and seagrass habitat loss associated with oiling may have negative effects on regional productivity over multiple generations (Mendelssohn et al. 2012), although such losses may not cause detectable site-specific decreases in fish density in the short term. Beyond habitat loss, oil contamination in sediments can remain elevated for decades in some habitats, with subtle, long-term effects on the fitness of sediment-associated species (Culbertson et al. 2008).

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Despite the significant lethal and sublethal threats posed by oil pollution, the life histories of estuarine fishes in the GOM may have promoted avoidance behaviors or compensatory mechanisms that reduced the overall population impacts of the Macondo spill in salt-marsh and seagrass habitats.

Behavioral avoidance. Many fishes are highly mobile and are likely capable of fleeing oil-affected shorelines, given the scales and spatial gradients of disturbance in coastal habitats following the Macondo spill. For marine fishes, the ability to seek refugia confers resilience against the effects of hydrocarbon pollution associated with offshore petroleum production platforms, despite quantifiable impacts for less-mobile invertebrates (e.g., crustaceans, echinoderms, other nonselective deposit feeders; Peterson et al. 1996). Indeed, flatfishes and sciaenids (e.g., spot, *Leiostomus xanthurus*) are capable of detecting and avoiding heavily oiled sediments, although they do not necessarily avoid lightly oiled sediments or food items (Moles et al. 1994, Hinkle-Conn et al. 1998). Furthermore, long-term periodic exposures to hydrocarbons in regions with natural background seepage such as the northern GOM may prime adaptive avoidance behaviors or tolerance in resident species (sensu Rosen et al. 2000, Van Veld and Nacci 2008).

Dilution. A significant fraction of the oil released from the [illegible]

have confirmed the activity of oil-degrading microorganisms within these marshes (Beazley et al. 2012). Despite low hydrocarbon concentrations in the water or fish tissues of coastal Louisiana, Whitehead and colleagues (2012) documented complex genomic and physiological responses of Gulf killifish to the spill. These data confirm that oil reached coastal environments at concentrations sufficient to cause biological responses in resident fishes and that dilution cannot explain the divide between organismal and population-level findings.

Compensatory processes. Density-mediated responses in vital rates, such as juvenile and adult survival and growth rates, may often be sufficient to overcome the impacts of oil exposure, which may result in little change at the population level. Such compensatory responses are frequently quite strong, and they underlie the resilience of marine fish populations to additional mortality sources, such as harvest (Neubauer et al. 2013). For example, a meta-analysis of stock–recruitment relationships (i.e., the survival rate between egg and juvenile

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