SIDEBAR: GUIDELINES FOR REDUCING AIR EXPOSURE IN CAPTURED FISH

Recreational Fisheries

With responsible fishing practices and the appropriate tools, there is rarely a need for air exposure durations to exceed 10 s. Lack of investment in the stewardship of fishery resources can be major contributors to mortality and poor handling in recreational fisheries. Thus, education plays an important role. Fish capture resulting in limited handling and no air exposure require that fish are hooked superficially (i.e., in the jaw), played for appropriate lengths of time (i.e., not to or beyond exhaustion), and unhooked while submerged in water. For the general welfare of the fish and to reduce air exposure, anglers should always use lines of appropriate breaking strength that will not extend fight durations and excessively exhaust fish (Landsman et al. 2011). Extensive air exposure can occur when removing deeply lodged hooks (Fobert et al. 2009), which can be avoided if appropriate tackle is used (Bartholomew and Bohnsack 2005) and hooks are set in a timely manner (Schisler and Bergeson 1996). The appropriate bait and hook types depend on the target species, but single barbless circle hooks (if using organic bait) and artificial lures, especially artificial flies, typically result in superficial hooking, short handling times, and limited tissue damage (Bartholomew and Bohnsack 2005). When landing a fish, although nets can cause damage and abrasion, cradles or knotless mesh nets are necessary for some fish and enable unhooking to occur while the fish is in water (Barthel et al. 2003). When fishers wish to photograph or measure their catch, underwater cameras and measuring tapes are essential tools. If these are not available, air exposure should still not exceed 10 s. After hook removal underwater, anglers can secure and support a fish's body with wet hands and gently lift the individual out of the water in time for an instant photograph, as shown in Figure 2A.

Commercial Fisheries

Excessive air exposure occurs in commercial fisheries when catches are very large or when removal of nontarget species is not prioritized. Releasing nontarget species immediately or sorting small batches of fish at a time could substantially improve survival of bycatch. Additionally, changes could be made to certain vessels to reduce air exposure such as incorporating sorting decks with water to prevent desiccation and having chutes overboard that allow fish to be discarded rapidly with minimal handling, as seen in Figure 2B. Stressors extend beyond those experienced during air exposure, however, and any change that minimizes handling and gear encounter times would reduce stress and mortality (Davis 2002). It may be possible to adjust fishing practices to reduce catch size (e.g., trawl or soak times), thereby reducing numbers of nontarget species as well as handling time on deck, without decreasing catch per unit effort (Davis 2002). High air temperatures or large temperature changes during capture can also play a significant role in bycatch mortality. Adjusting fishing effort to cooler seasons, altering deck conditions to provide shade, or misting seawater would improve survival (Davis 2002). For severely impaired fish, certain fish revival techniques have proven effective (e.g., recovery boxes that provide assisted gill ventilation; Farrell et al. 2001) and allowing for recovery time onboard with recirculating water may improve survival for some fishes. However, these methods may only be useful if the fish is severely impaired (e.g., cannot maintain equilibrium; see Robinson et al. 2013). Although fish welfare issues should be considered in commercial fisheries and air exposure reduced as much as possible, it will take education, willingness, and potentially regulatory change to implement alternative handling methods. However, it is prudent that research regarding release of bycatch in commercial fisheries moves beyond simply characterizing composition and mortality rates to examining methods that reduce mortality.

cial for fish, no matter how short the duration. Nonetheless, air exposure is common in many fish capture scenarios and is sometimes protracted. There are numerous interacting factors at play during capture and handling; therefore, quantifying responses to air exposure without including other relevant stressors (e.g., exercise) provides a conservative estimate of the overall effects of capture. Because air exposure can be easily monitored, identifying species-specific threshold air exposure durations is nonetheless important for the development of fisheries management regulations and voluntary "best practices" guidelines. Fishers should be provided with information regarding air exposure that is more explicit than simply to "minimize," which is both subjective and confusing. Although thresholds have been determined for some fisheries and species, continued research and education will be central to this issue. Unfortunately, there will never be a silver bullet or "one-size-fits-all" recommendation, and scientific results will be inevitably context specific.

The consequences of air exposure for fish in terms of survival and reproductive capacity can violate the core assumptions upholding the management strategy of releasing fish. Given currently available literature, we recommend less than 10 s of cumulative air exposure for captured fish to be released as a cautious target. As detailed previously, a difference of just 10 s air exposure was indeed sufficient to reduce fecundity in Atlantic Salmon (Richard et al. 2013). Although other research has found resiliency to longer durations in some species, in the interest of fish welfare, the goal should be to reduce air exposure as much as possible, thus aiming for no more than 10 s. In fisheries where this is not possible, a similarly cautious target needs to be set. A 10 s limit is attainable in recreational fisheries, where with access to appropriate tools there is little need for air exposure for unhooking, measuring, or photographing fish (appropriate photographing technique shown in Figure 2). Extreme care should especially be taken to reduce air exposure when the landed fish is exhausted, water temperatures are beyond the normal range, or with known sensitive species. The same principles apply to commercial fisheries, but managing air exposure duration is much more difficult, often gear dependent, and very few species/fisheries have been examined. For those species that have been assessed, little information exists pertaining to the sublethal or long-term effects of air exposure to released fish. This is an area that could greatly benefit from more research. In many commercial fisheries, reducing air exposure duration to less than 10 s would require changing methods (e.g., depositing fish directly into water-filled totes; Figure 3A) or gear (e.g., sorting tables with water to prevent desiccation or chutes to rapidly discard fish; Figure 3B). A further consideration with large commercial catches is that oxygen depletion of water in crowded conditions

Figure 2. Although air exposure should be avoided, there are certain handling practices and tools that can be adopted to improve fish welfare and reduce air exposure. In recreational angling, unhooking and measuring can happen underwater, and if a photo must be taken, the angler should secure and support the fish's body with wet hands and barely lift the individual out of the water in time for an instant photograph. Photo by Vivian Nguyen.

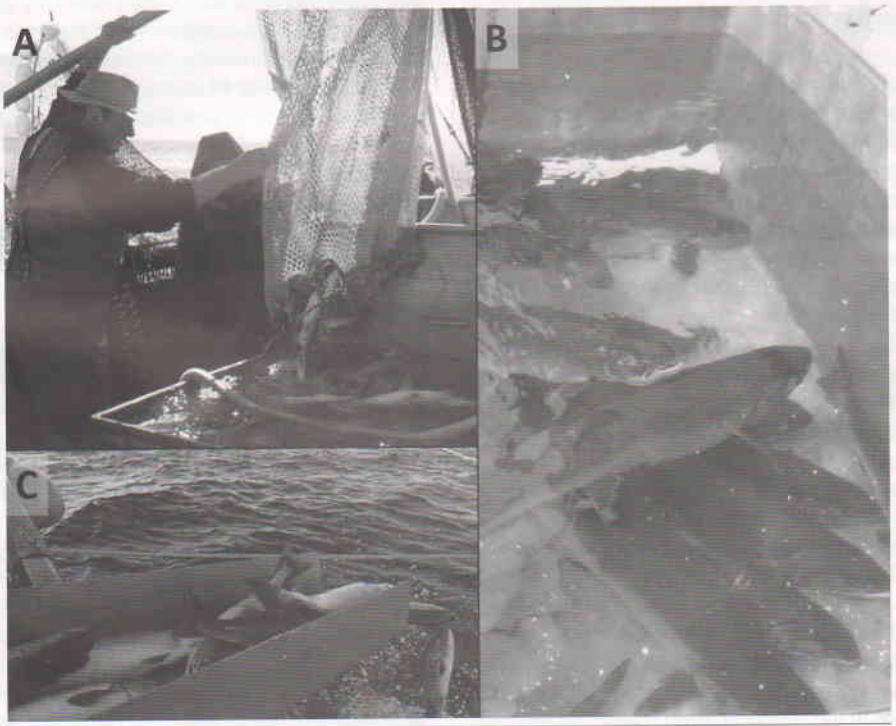

Figure 3. (A) In commercial fisheries, reducing or eliminating air exposure requires gear-specific or methodological changes. Fish can be brailed right into water-filled totes in some fisheries to eliminate air exposure. Photo by Graham Raby. (B) Alternatively, sorting small batches of fish at a time on a sorting table, rather than on deck, with a chute to release fish overboard reduces air exposure duration, handling time, and probability of injury. Photo by Katrina Cook. (C) Finally, giving incidentally captured fish recovery time in a tote with flow-through water can reduce stress and mortality. Photo by Graham Raby.