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EDITORIAL

Tunas and their fisheries: safeguarding sustainability in the twenty-first century

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Tunas (family Scombridae, tribe Thunnini) (Fig. 1), collectively support one of largest fisheries in the world (in terms of both landings and economic value) yet they are top level carnivores living in the pelagic environment which has rates of primary productivity (per unit area) approximately one tenth those of coastal areas (e.g. Westberry et al. 2008). Tunas are also unique among fishes in many of their anatomical, biological, and physiological attributes (Block and Stevens 2001) which permit their extraordinary growth and reproductive rates (e.g. Brill 1996; Gaertner et al. 2008; Gaikov et al. 1980; Wild 1986). Tunas are, however, not a homogenous group. Rather, as described by Bernal et al. (2017) there are demonstrable species-specific differences in their physiological abilities and tolerances that allow some to make extensive vertical movements (e.g. Musyl et al. 2003; Lowe et al. 2000; Bernal et al. 2009; Galli et al. 2009; Schaefer and Fuller 2002; Schaefer et al. 2009; Shiels et al. 2015), or to undertake migratory patterns which take them from temperate feeding areas to tropical spawning areas (e.g. Block et al. 2001; Sibert et al. 2006; Wilson et al. 2005).

The relationship of tunas to their environment (i.e. the effects of oceanographic conditions on movements, distribution, and catchability) has been a topic of interest for decades (e.g. Barkley et al. 1978; Sund et al. 1981). This area of investigation is now becoming increasingly important as the effects of climate change becomes more apparent in the pelagic environment (e.g. Kimura et al. 2010; Lehodey et al. 2011; Hobday et al. 2013). Recent studies relating climate change to changes in movements and distributions of tunas (e.g. Del Raye and Weng 2015; Mislan et al. 2017) are built on the foundation of physiological studies on tunas undertaken specifically to define the characteristics of species-specific suitable habitats, as well as environmental conditions that restrict movements and distribution (reviewed by Brill 1994 and Bernal et al. 2017).

Interweaving of the disparate scientific disciplines of tuna physiology and fishery science (e.g. Brill et al. 2005; Brill and Lutcavage 2001) has also led to significant efforts to correct catch-per-unit effort data by differentiating changes in apparent abundance (i.e. population size) from changes in catchability (e.g. Bertrand et al. 2002; Bigelow et al. 2002; Bigelow and Maunder 2007). The importance of modelers, fishery biologists, and physiologists working interactively is now recognized as being necessary to translate

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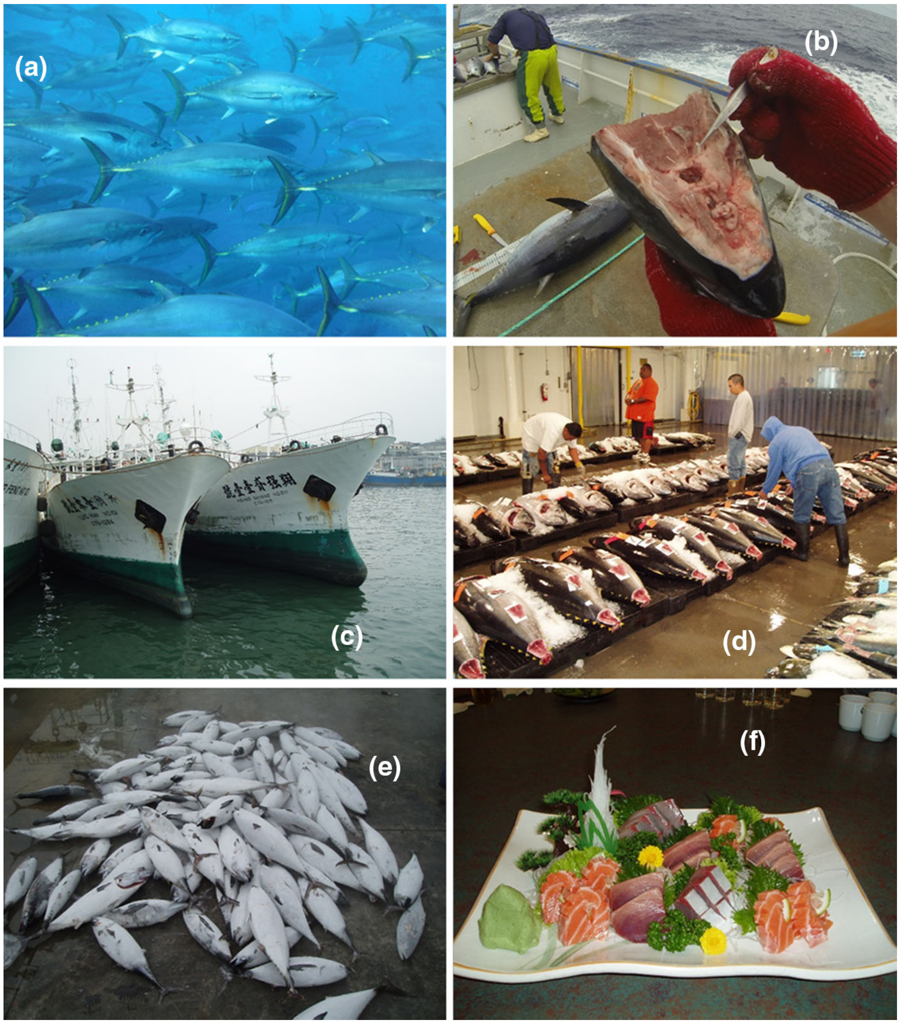

Fig. 1 **a** Tuna undertake long-distance migrations and can be found in large schools, **b** otoliths collected from tuna heads are used in age and growth studies, **c** fleets of long-line and purse seine vessels seek tuna in all the major oceans, **d** high value tuna species (e.g. yellowfin, bluefin and bigeye tunas) are sold in fresh fish markets, **e** low value species (e.g. skipjack tuna and albacore) are destined for canaries, **f** high value species are an important element in sashimi and sushi (all pictures © Alistair Hobday)

mechanistic physiological understanding into effective fisheries management and conservation strategies (Hobday et al. 2013; Horodysky et al. 2015, 2016; McKenzie et al. 2016). These types of inter-disciplinary collaborations include predictions of the effects of oceanographic conditions on the distributions of different tuna species and thus their vulnerability to specific fishing gear (e.g. Hobday 2010; Lehodey et al. 2015). Despite decades of study, there is still much to understand. New technologies are, however, playing an important role in elucidating trophic dynamics and species-specific reliance on different trophic pathways (Young et al. 2015; Duffy et al. 2017).

Several of the reviews in this issue also provide syntheses of the species-specific spawning habitats, feeding ecologies, vertical movements, and migratory patterns of targeted tuna species with the objectives of elucidating both commonalities and differences. Given the economic importance of the fisheries exploiting tunas, and the continuing changes in the environmental conditions of the pelagic environment in the twenty-first century, most papers also take into account the likely impacts of changes in climate and fishing pressure—critical for ensuring sustainability. More specifically, Muhling et al. (2017) summarize the reproductive movements and habitats sought by breeding tunas, many of which have restricted spawning grounds (e.g. Richardson et al. 2016). The impact of climate change on spawning regions may lead to declining spawning activity and movement to new areas (e.g. Muhling et al. 2015, 2016), which will be a challenge for management and assessment.

As with movements between feeding and spawning grounds, the growth rates of tunas varies between the tropical and temperate species group (e.g. Fromentin and Fonteneau 2001). Murua et al. (2017) describe the age-specific patterns of growth, and implications for population dynamics and fisheries management. They show that tunas have evolved different growth strategies which have implications for fisheries management. Species with faster growth rates generally support higher catch levels than species with slower growth rates, which can be problematic when multiple species are targeted in the same fishery. Specific syntheses of information on yellowfin tuna is presented by Pecoraro et al. (2017), while Nikolic et al. (2017) cover albacore tuna. Both contributions describe the biology, ecology, fisheries status, stock structure and management of these species. While much is known, environmentally-driven changes in stock distribution still needs to be integrated into their respective stock assessments. This integrated understanding of biology, fisheries and the economic forces driving exploitation is required for effective international management and conservation.

The changing nature of tuna fisheries are not just about tuna biology nor national and international regulation. The interactions of tuna fisheries with bycatch species, is also driving the restriction of areas and times of operation, and specific gear configurations. Hall et al. (2017) describe bycatch trends and patterns in tuna fisheries, along with approaches being implemented to reduce bycatch. Importantly, they describe market strategies and stakeholder education efforts that are often overlooked in bycatch management.

The local, regional and global markets obviously influence tuna fisheries, with economic forces and supply chains relatively underappreciated in research to date (Mullon et al. 2017). Tuna products are amongst the most widely traded seafood with global trade established early in the development of tuna fisheries (Fig. 1). Guillotreau et al. (2017) report a high degree of market integration and competition through prices at the global level and address a range of questions related to consumer responses to price changes, economic incentives for quota reduction and targeting of tuna species according to the relative price.

Collectively, the reviews presented herein build on recent compilations of tuna research (Kitagawa and Kimura 2015; Hobday et al. 2017), which was reinvigorated in the early 2000 s with large scale tagging programs (e.g. Block et al. 2003) and the initiation of the Climate Impacts on Oceanic Top Predators (CLIOTOP) research program (Lehodey and Maury 2010). To sustain tuna harvests and sustainable populations into the twenty-first century, however, greater attention must be given to continuing integration of disparate areas of study and biological organization—from physiology to movements, harvests to fisheries management and effective resource and conservation strategies, and eventually to markets and consumers.

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