Global Ecology and Conservation 14 (2018) e00388

Contents lists available at ScienceDirect

Global Ecology and Conservation

journal homepage: http://www.elsevier.com/locate/gecco

Original Research Article

Global conservation status of marine pufferfishes (Tetraodontiformes: Tetraodontidae)

Emilie Stump [a], Gina M. Ralph [a], Mia T. Comeros-Raynal [a, b], Keiichi Matsuura [c], Kent E. Carpenter [a, *]

[a] IUCN Marine Biodiversity Unit, Global Species Programme, Biological Sciences, Old Dominion University, Norfolk, VA, USA
[b] ARC Centre of Excellence for Coral Reef Studies, James Cook University, Townsville, Queensland, 4811, Australia
[c] Division of Fishes, National Museum of Nature and Science, Tuskuba, Ibaraki, 305-0005, Japan

ARTICLE INFO

Article history:
Received 15 January 2018
Received in revised form 10 April 2018
Accepted 10 April 2018

ABSTRACT

Puffers are biologically and ecologically fascinating fishes best known for their unique morphology and arsenal of defenses including inflation and bioaccumulation of deadly neurotoxins. These fishes are also commercially, culturally, and ecologically important in many regions. One-hundred-and-fifty-one species of marine puffers were assessed against the International Union for Conservation of Nature (IUCN) Red List Criteria at a 2011 workshop held in Xiamen, China. Here we present the first comprehensive review of puffer geographic and depth distribution, use and trade, and habitats and ecology and a summary of the global conservation status of marine puffers, determined by applying the International Union for Conservation of Nature (IUCN) Red List Criteria. The majority (77%) of puffers were assessed as Least Concern, 15% were Data Deficient, and 8% were threatened (Critically Endangered, Endangered or Vulnerable) or Near Threatened. Of the threatened species, the majority are limited-ranging habitat specialists which are primarily affected by habitat loss due to climate change and coastal development. However, one threatened puffer (*Takifugu chinensis* – CR) and four Near Threatened puffers, also in the genus *Takifugu* (which contains 24 species total), are wide-ranging habitat generalists which are commercially targeted in the international puffer trade. A disproportionate number of species of conservation concern are found along the coast of eastern Asia, from Japan to the South China Sea, with the highest concentration in the East China Sea. Better management of fishing and other conservation efforts are needed for commercially fished *Takifugu* species in this region. Taxonomic issues within the Tetraodontidae confound accurate reporting and produce a lack of resolution in species distributions. Resolution of taxonomy will enable more accurate assessment of the conservation status of many Data Deficient puffers.

* Corresponding author.
E-mail address: kcarpent@odu.edu (K.E. Carpenter).

https://doi.org/10.1016/j.gecco.2018.e00388

1. Introduction

Fishes of the order Tetraodontiformes (412 extant species in 10 families; Matsuura, 2014) are globally distributed in tropical and temperate seas and freshwaters. Their great diversity of size, structure, and behavior have attracted the attention of ichthyologists and biologists around the world (Matsuura, 2014; Tyler, 1980). The Tetraodontidae, henceforth simply called puffers (Nelson, 2006), are the largest family within the order Tetraodontiformes with 184 recognized species in 27 genera (Matsuura, 2014). They are most diverse in shallow, warm, tropical and temperate seas with some species entering brackish and freshwaters (Alfaro et al., 2007; Matsuura, 2014; Tyler, 1980) and 30 species occurring exclusively in freshwater (K. Matsuura pers. comm. 2015).

Puffers are notable for their arsenal of defenses including inflation and the use of potent toxins to deter predation. Inflation of the body as a form of predator defense is a major functional innovation exhibited by the puffers and their sister family, the Diodontidae (porcupinefishes). Inflation deters predation by making the prey item too large for potential predators to ingest (Wainwright et al., 1995; Wainwright and Turingan, 1997). In addition to inflation, puffers bioaccumulate and deploy potent neurotoxins which are thought to primarily serve as predator deterrents (Kodama et al., 1985; Miyazawa and Noguchi, 2001; Noguchi and Arakawa, 2008; Saito et al., 1985). Tetrodotoxin is the most notorious of puffer neurotoxins, however other neurotoxins such as saxitoxin can co-occur or are sometimes the dominant compound (Landsberg et al., 2006). Tetrodotoxin is highly toxic to humans and can cause rapid fatality preceded by symptoms such as gastrointestinal distress, numbness, paralysis, and respiratory failure (Isbister et al., 2002). Despite their toxicity, and in some cases because of it, puffers have a long and rich culinary history in East Asian cultures including China, Korea, and Japan (Ishige, 2001).

Puffer culinary preparations can range from low-value stews and processed fish products to extravagantly priced luxury commodities (NMFS, 1989). In Japan, two of the most desirable species, the Ocellate Puffer *Takifugu rubripes* and the Chinese Puffer *Takifugu chinensis*, sold for about 8000−15,000¥/kg ($65-$123/kg) at Haedomari Fish Market, a specialized puffer market in Shimonoseki City, in the 2010s (K. Matsuura pers. comm. 2015). These highly-desirable species are usually served in expensive restaurants as artfully arranged, thinly-sliced sashimi. Due to the potential to cause human fatality, puffer preparation is regulated through a national chef licensing program in Japan (Ishige, 2001) and is subject to strict import regulations, factors which may contribute to the elevated value of puffer species. However, exaggerated value can also be a result of increasing rarity, which can fuel the disproportionate exploitation of species (Courchamp et al., 2006). While puffer species have been locally harvested for food and/or medicine for centuries in East Asia and elsewhere, modern fishing, aquaculture and transportation technologies have enabled the demand for puffer to be supplied by global trade or supplemented by aquaculture (Kawata, 2003, 2012; NMFS, 1989). The introduction of modern fisheries techniques have depleted many commercial fish stocks worldwide (Hutchings, 2003; Myers and Worms, 2003). Overexploitation has been identified as the primary driver of localized and global extinction in marine populations (Dulvy et al., 2003) and there are indications that some puffer populations have been adversely affected by fishing to supply high demand (Kawata, 2003, 2012). For example, the Tiger Puffer, *Takifugu rubripes*, is the most expensive and preferred among puffers in Japan and experienced drastic localized declines in biomass since the late 1980s due to targeted fishing leading to overexpoitation of the resource (Kawata, 2012). As the most highly desirable species have become rare, fishers have switched targets to formerly less desirable species which have been subsequently overexploited (Kawata, 2003).

The global conservation status of puffer populations has not been previously examined. As part of an ongoing initiative to assess the global status of 20,000 key marine species (Dulvy, 2013) for the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (IUCN, 2012), we assembled the first assessment of the global conservation status of 151 marine puffers, resulting in the first comprehensive review of their geographic and distribution, use and trade, and habitat and ecology and a summary of their global conservation status, determined by applying the International Union for Conservation of Nature (IUCN) Red List Criteria. Research and conservation priorities are then identified based on this work.

2. Methods

2.1. Red List process

The 151 globally recognized marine and estuarine puffers were assessed (the 33 species of freshwater puffers are not included in this analysis) using the IUCN Red List Categories and Criteria (IUCN, 2012). The majority were assessed during a workshop held in Xiamen, China in 2011. The conservation status of Tropical Eastern Pacific endemics was determined in 2008, and three species were assessed using the sampled approach to the Red List Index in 2009. The recently described *Canthigaster criobe* (Williams et al., 2012) and validated *Canthigaster petersii* (Allen and Erdmann, 2012) were assessed via electronic consultation with experts. A pending Red List assessment for the newly-described *Torguigener albomaculosus* (Matsuura, 2015) is not included in these results.

IUCN Red List evaluations are a rigorous process that includes follow-up consultation with experts and several IUCN internal reviews prior to publication on the IUCN Red List of Threatened Species website (http://www.iucnredlist.org). This involved process ensures that comprehensive, quantitative measures of extinction risk are applied and that the best available data are used to make these conservation determinations (Mace et al., 2008).

The IUCN Red List is based on the general idea that species with small geographic ranges or those exhibiting rapid population declines are at a higher risk of extinction (Mace et al., 2008; IUCN, 2012). Based on these two paradigms, five