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Giant jelly eaters on the line: Species distribution and bycatch of three dominant sunfishes in the Southwest Pacific

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ABSTRACT

The ocean sunfishes have a long and confusing taxonomic legacy, clouding the global zoogeography of each species and hindering fisheries bycatch assessments. The traditional view of *Mola mola* as the most common sunfish species worldwide is challenged by our findings from Australia and New Zealand, revealing that three large sunfishes, *Masturus lanceolatus*, *Mola alexandrini* and *Mola tecta,* dominate the tropical/subtropical, warm-temperate and cold-temperate waters here, respectively, while *Mola mola* – both Pacific and Atlantic clades – is relatively rare. These findings were based on phylogenetic (mtDNA D-loop) and/or morphological species identification of sunfish from longline bycatches ($n = 106$), natural history museum collections ($n = 45$) and other sources ($n = 12$), informed by recent advances in the taxonomy of the genus *Mola*. Furthermore, separation in species distributions were seen when comparing sampling latitude and sea surface temperature. The findings imply that the longline fisheries observer sunfish data from Australia and New Zealand is a mix of species, and not dominated by *M. mola* as previously assumed. Mean catch per unit Effort (2001–13) in 1° latitude/longitude grids off Pacific Australia and New Zealand were predominantly < 1 sunfish.1000 hooks^{-1} (up to 6.5 in some areas) with no statistical significant upwards or downwards trends detected over time in four fishing ground sub-areas, each presumably dominated by either *Masturus lanceolatus*, *Mola alexandrini* or *Mola tecta*. Widespread specimen identification errors had previously obscured a more complex Molidae zoogeography in the area, highlighting that phylogenetic analyses of sunfish bycatch globally would benefit species-level conservation status evaluations.

1. Introduction

The ocean sunfishes (genera *Mola* and *Masturus*, Family Molidae) are a somewhat overlooked group of large teleosts, infamous for their odd shape resembling 'swimming heads' without tails, and for including the world's heaviest bony fish (Sawai et al., 2018). They are difficult to study, but with the advances in modern technology they have experienced a surge in research in recent years, revealing they are not the peculiar, sluggish oddities of nature they have traditionally been considered (e.g. Cartamil and Lowe, 2004; Watanabe and Sato, 2008). Instead, their diet and evidently high numbers worldwide suggest they play an important ecological role as predators of gelatinous zooplankton (Breen et al., 2017; Grémillet et al., 2017; Phillips et al., 2017). Advances in telemetry, digital imagery and other technologies continue to confirm that ocean sunfish are active predators, hunting at depth in dynamic frontal systems (Nakamura et al., 2015; Thys et al., 2015; Sousa et al., 2016a; b). However much of their life history is still unknown, as is the global zoogeography of all taxa in the family.

Currently, five species in three genera are recognized in the Molidae, namely the small Slender sunfish *Ranzania laevis*

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(Pennant, 1776), the Sharptail sunfish *Masturus lanceolatus* (Liénard, 1840), the Ocean sunfish *Mola mola* (Linnaeus, 1758), the Bump-head sunfish *Mola alexandrini* (Ranzani, 1839) (Sawai et al., 2018), and the newly described Hoodwinker sunfish *Mola tecta* (Nyegaard et al., 2017) (Eschmeyer et al., 2017; Froese and Pauly, 2017). All five species obtain large adult sizes of > 2.4 m in total lenght (> 3 m for some species) (Gudger and MacDonald, 1935; Nyegaard et al., 2018; Sawai et al., 2018). The current Molidae taxonomy is a modification of Fraser-Brunner (1951), updated with recent insights from molecular and morphological studies. Briefly, the genetic clade *Mola* sp. A of Yoshita et al. (2009) was recently equated to *M. alexandrini*, a valid, senior synonym of *M. ramsayi* (Sawai et al., 2018), while *Mola* sp. C of Yoshita et al. (2009) was described as a new species, *M. tecta* (Nyegaard et al., 2018). The third clade, *Mola* sp. B of Yoshita et al. (2009), has been equated to *M. mola* (Yoshita et al., 2009; Matsuura, 2014; Sawai et al., 2018), with residual uncertainties in the nomenclature, as this species appears to include two basin-wide groups (Atlantic vs Pacific), as revealed by phylogenetic analysis (Bass et al., 2005; Ahuir-Baraja et al., 2017; Sawai et al., 2017). Here, the nomenclature follows Sawai et al. (2018) by treating *Mola* sp. B as a single species, *M. mola*, awaiting taxonomic resolution of the two genetic clades, which are herein referred to as Atlantic and Pacific *M. mola*, respectively. Within *M. alexandrini*, a 'subtropical' and a 'temperate' group have been infered from phylogenetic analysis (Yoshita et al., 2009; Ahuir-Baraja et al., 2017).

1.1. Distribution and interactions with fisheries

To date, the majority of ecological and biological research on the Molidae has been undertaken on *M. mola* in the northern hemisphere. Anecdotally, this is considered to be the most common of the large sunfish species globally, with a worldwide distribution in temperate and tropical waters (Pope et al., 2010; Jing et al., 2015; Froese and Pauly, 2017). However, a legacy of taxonomic confusion (Nyegaard et al., 2018; Sawai et al., 2018) has obscured a more complex zoogeographical pattern within the *Mola* species. The traditional view of *M. alexandrini* being restricted to the South Pacific, with sympatric occurrence with *M. mola* in Australian waters (Fraser-Brunner, 1951), has been challenged in recent years, as molecular, morphological and ecological studies have confirmed that *M. alexandrini* is found over a wide range in both hemispheres (Yoshita et al., 2009; Thys et al., 2013, 2016; Ahuir-Baraja et al., 2017; Sawai et al., 2018). Prior to its recent description, *Mola tecta* was mistaken for *M. mola* or *M. ramsayi* (now *M. alexandrini*) and while *M. tecta* appears to have a circumpolar distribution in temperate waters of the southern hemisphere (Nyegaard et al., 2018), little is known of this recently described species. *Masturus lanceolatus* is considered to be widely distributed throughout the tropics (Jing et al., 2015; Froese and Pauly, 2017) but little has been published on this species, despite it being subjected to a targeted fishery in Taiwan (Liu et al., 2009).

Ocean sunfishes are caught as bycatch in various fisheries around the world and their bycatch is thought to be so significant that recently, *M. mola* was listed by the International Union for the Conservation of Nature (IUCN) as 'Vulnerable' globally. The concerns stem, in part, from the high level of estimated bycatch in the South African longline fishery (Sims et al., 2009), and the possibility that longline bycatch elsewhere may be similarly high (Jing et al., 2015). Large total bycatches, as well as rapid declines in the total bycatch of *M. mola* in other types of fisheries were also identified as of concern. However, a paucity of analysis of long-term fisheries bycatch data in most parts of the world prevents a more detailed assessment (op. cit.). The other large sunfish species are either not considered of concern by the IUCN (*Masturus lanceolatus* is currently considered of 'Least Concern'), or are not assessed (*M. alexandrini* and *M. tecta*).

1.2. Sunfishes in Australia and New Zealand

Knowledge of the species identity of sunfish in Australian and New Zealand waters stems mainly from museum collections and information collected from fisheries. Ocean sunfishes are caught as bycatch in the Australian and New Zealand longline fisheries for tuna and billfish (Griggs and Baird, 2013; Tuck et al., 2013), where data have been recorded for more than a decade. In Australia, they are predominantly recorded by fisheries observers as 'Unspecified Molidae' or *M. mola*, and evaluated by management as a mix of *M. mola* and *M. alexandrini* (Ward and Epe, 2008; Tuck et al., 2013). Both *M. mola* and *M. alexandrini* are listed as "High Risk" bycatch species in the longline fishery off eastern Australia, with robust impact assessments hindered by a paucity of data on life history and post-release survival (Ward and Epe, 2008; AFMA, 2013, 2014). In New Zealand, all sunfish longline interactions are recorded and managed as *M. mola* (Francis et al., 1999; Griggs and Baird, 2013; MPI, 2016a). Similar broad sunfish bycatch categories, including the generic use of "*M. mola*", are also common in longline fisheries in other parts of the world (e.g. Petersen, 2005; Fulling et al., 2007; Burgess et al., 2010; Domingo et al., 2012; Cambiè et al., 2013; Clarke et al., 2014).

Although four large Molidae species are currently listed from Australian waters (i.e. *Ma. lanceolatus*, *M. mola*, *M. alexandrini* and *M. tecta*; Hutchings, 2001; Bray, 2008; Fishes of Australia, 2017), *M. mola* has long been considered the most common species here (e.g. Pope et al., 2010; Atlas of Living Australia, 2017). In New Zealand, *M. mola* was traditionally listed as the only large sunfish species (Parrott, 1960; McCann, 1961; Doak, 1972), with the later addition of *Ma. lanceolatus* (Paulin et al., 1982; Paul and Heath, 1997; Paul, 2000). A recent review of the Molidae in New Zealand, however, listed *Ma. lanceolatus* and *M. alexandrini*, while excluding *M. mola* (Roberts et al., 2017; Stewart and Struthers, 2015). In recent years, phylogenetic analyses of a small number of sunfish samples from Australia and New Zealand have confirmed that all four large sunfish species are indeed present in the region, i.e. nesting in the *Ma. lanceolatus* ($n = 1$), *M. alexandrini* ($n = 7$), *M. tecta* ($n = 14$) and *M. mola* ($n = 2$) clades (Yoshita et al., 2009; Yamanoue and Sawai, 2012; Nyegaard et al., 2018), however the relative abundance and distribution of each species is not known.

The objectives of this study are to determine which of the large species of Molidae (i.e. excluding *R. laevis*) most commonly occur in Australia and New Zealand waters, whether the distribution patterns differ between species, if they are associated with different sea surface temperature regimes, and if longline by-catch data reveal a decreasing pattern over time. Sunfish skin samples were obtained from longline bycatches, museum collections and stranding events, and the species identity determined phylogenetically. A review was also undertaken of sunfish specimens held in museum collections in Australia and New Zealand, with the species confirmed morphologically, according to recent advances in the taxonomy of the *Mola* genus (Nyegaard et al., 2018; Sawai et al., 2018). Taking all data sources into consideration, the distribution of each species was examined in relation to latitude and satellite sea surface temperature (SST). Based on the results, catch per unit effort (CPUE) was calculated from long-term fisheries observer longline bycatch data from Australia and New Zealand, as a proxy for sunfish abundance, to identify any decreasing trends within selected areas of the overall fishing grounds. Finally, overall CPUEs were compared with the rates of sunfish bycatch in the South African longline fishery.