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RESEARCH ARTICLE

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Conservation implications of angler misidentification of an endangered fish

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Abstract

1. Conservation strategies for endangered species often include protection from harvest by humans. Correct species identification is paramount for this form of management to be effective.
2. Trout cod (*Maccullochella macquariensis*) is a threatened Australian freshwater fish, occupying habitats in the southern Murray–Darling basin. Trout cod, although protected from angling, morphologically resemble Murray cod (*Maccullochella peelii*), a species that is a key target of recreational anglers.
3. During a long-term mark–recapture study, angler return data were collected both for Murray cod and trout cod.
4. Up to 40% of trout cod captured were identified by anglers as Murray cod, and the chance of misidentification increased with the increasing size of trout cod, implying that this species could be inadvertently retained by anglers. Moreover, unnecessary angling mortality of adult breeding individuals is likely to delay the time for recovery of this threatened species.
5. As a large and vocal user group, anglers can play a key role in promoting the conservation of aquatic areas and fish species. There is a need for anglers and fishery managers to understand this problem and to work together on a solution, through the tighter enforcement of regulations where trout cod are present, and through an increased emphasis on education.

KEYWORDS

angling, endangered, fish, harvest, misidentification, Murray cod, population, recreational, threatened, trout cod

1 | INTRODUCTION

Conservation of endangered animal species across environments occupied by humans is complex. For freshwater fishes, stresses arise not only from habitat alteration and the introduction of invasive animals, but also in the form of exploitation as food by humans (Arthington, Dulvy, Gladstone, & Winfield, 2016; Koehn et al., 2013). Fortunately, in many countries where subsistence fishing is not common, there has been an increasing emphasis on the conservation of fisheries resources (McIntyre, Reidy Liermann, & Revenga, 2016), often led largely by the recreational angling community (Granek et al., 2008). Over the past 20 years, there has been a clear shift globally by the angling community away from a 'harvest' mentality towards becoming stewards of fishery resources (Cooke et al., 2013). Indeed, fishery managers are increasingly turning to the angling community as custodians of threatened fish recovery (Cooke et al., 2013), with groups such as the Australian Trout Foundation (in south-eastern Australia) now working with scientists and conservation groups to protect endangered galaxiids from predation by introduced trout, by installing barriers to prevent incursion into key galaxiid habitats. Despite such advocacy and good work, however, recreational angling can still have negative impacts on fish populations.

Species misidentification, with the consequent inadvertent retention of protected or threatened species, is one potential impact of recreational angling and fishing generally (Beerkircher et al., 2009). Misidentification by anglers has been shown to be prevalent in populations of the endangered bull trout (*Salvelinus confluentus*) and westslope cutthroat trout (*Oncorhynchus clarki lewisi*) in west Central Montana, USA, where there were high rates of confusion between these threatened species and more common species (Schmetterling & Long, 1999). Resident and more experienced anglers, however, were able to identify the threatened species better than non-resident and less experienced anglers (Schmetterling & Long, 1999).

Trout cod (*Maccullochella macquariensis*) is a long-lived (20 years), large-bodied species, with a maximum size of 16 kg and 850 mm total length (Harris & Rowland, 1996). The species has undergone declines in distribution and abundance to the extent that it is now listed as nationally Endangered under the Commonwealth Environment Protection and Biodiversity Conservation (EPBC) Act 1999. Trout cod currently occupy a range of habitats, but are naturally riverine and strongly associated with large woody instream habitats (Lyon et al., 2012; Nicol, Barker, Koehn, & Burgman, 2007). As such, habitat degradation and river regulation are thought to be major drivers of their decline (Koehn et al., 2013; Lintermans, 2009). Both historical and recent fishing mortality are also thought to have contributed to the decline of this species (Todd, Nicol, & Koehn, 2004; Trout Cod Recovery Team, 2008). Trout cod are voracious predators, and are often captured by anglers as by-catch when fishing for other species with a legal take, such as the highly prized Murray cod (*Maccullochella peelii*) and golden perch (*Macquaria ambigua*) (Trout Cod Recovery Team, 2008). Across most of their current range, trout cod coexist with Murray cod, and given the morphological similarities of these species (Lintermans, 2009, Figure 1) the potential for misidentification by anglers is high. As such, we propose that despite the protection of the species from take, negative impacts from recreational angling continues and therefore restricts the recovery potential of the remaining trout-cod populations.

Nineteen years of angler return data from a mark–recapture programme were analysed to determine rates of misidentification between the large-bodied endemic species of the Murray River (Murray cod, golden perch, trout cod, and silver perch). In particular, the analysis focused on the interaction between morphologically similar trout cod and the popular recreational species, Murray cod. We hypothesized that there would be a small rate of misidentification between trout cod and Murray cod.

FIGURE 1 Tagged trout cod (top) and Murray cod (bottom)

2 | METHODS

2.1 | Study site

The study was undertaken in the Murray River, south-eastern Australia, between Yarrawonga and Tocumwal (Figure 2). This reach of river is highly significant for trout cod, and in the 1990s supported the only naturally occurring population of this species left in the wild (Koehn et al., 2013). This area of river, which on one side is bounded by state forest, is extremely popular with anglers and campers, and so is heavily fished, including by large numbers of anglers who are not frequent visitors to the area. Fish were captured using electrofishing and marked using standard tagging methods, as outlined in Koehn et al. (2008).

During annual surveys, captured fish were weighed (to the nearest gram) and measured (total length (TL) and/or fork length (FL), to the nearest millimetre). A uniquely coded external t-bar or dart tag was inserted on the left side of each fish (>200 mm in total length), adjacent to the dorsal fin, and displayed a telephone number for anglers to report the relevant capture data (species, date, place of capture, and fish length). All fish outside the legal slot limit were assumed to be returned to the water by anglers. Information on the fate of fish within the slot limit was not collected.

2.2 | Analysis

Of the four species encountered, only the misidentification and imprecision rates between trout cod and Murray cod were analysed. The misidentification rate is the probability that a recreational fisher misidentifies a given species, and is conditional on the true species (Table 1). The trout cod misidentification rate is then:

$$\text{Misidentification rate}_{\text{Trout Cod}} = \frac{\text{False Murray Cod}}{\text{Total Trout Cod}}.$$

The imprecision rate is the probability that a fish is not actually what the recreational fisher has identified it as being, and is

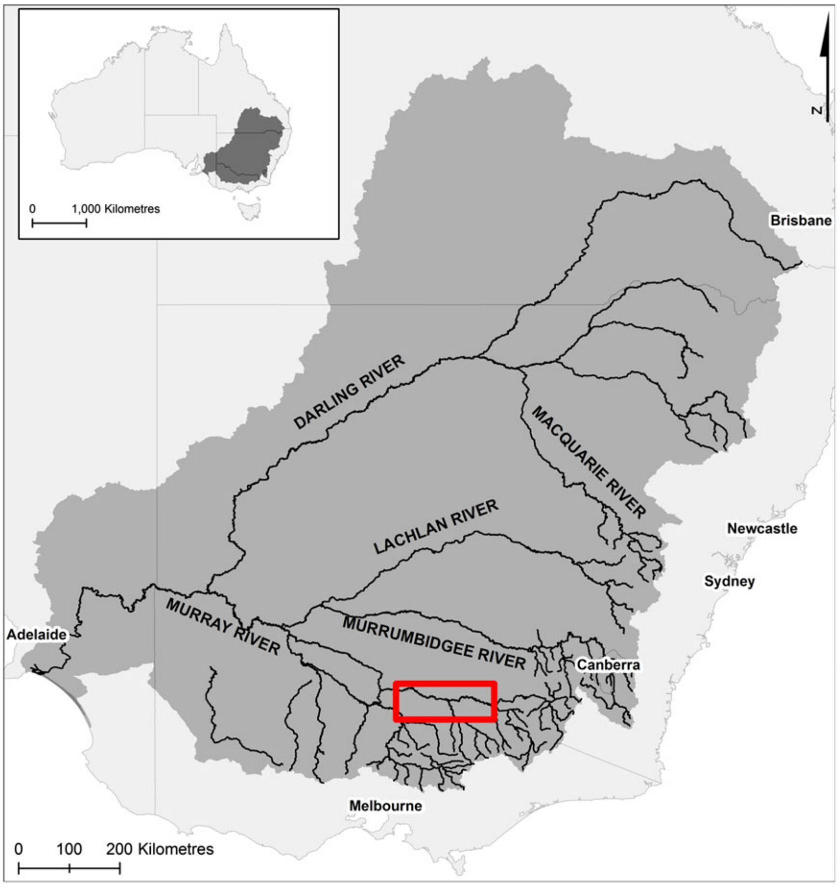

FIGURE 2 Study site

TABLE 1 Confusion matrix for identifying a fish as Murray cod or trout cod. The confusion matrix shows the four possible outcomes for each reported fish. The four options are: Murray cod correctly identified as a Murray cod (True Murray cod); Murray cod identified as trout cod (False trout cod); trout cod identified as Murray cod (False Murray cod); or trout cod identified as trout cod (True trout cod)

		Reported species		
		Murray cod	trout cod	
True species	Murray cod	True Murray cod	False trout cod	Total Murray cod
	trout cod	False Murray cod	True trout cod	Total trout cod
		Reported Murray cod	Reported trout cod	

conditional on the reported fish species. The trout cod imprecision rate is then:

$$\text{Imprecision rate}_{\text{Trout Cod}} = \frac{\text{False Trout Cod}}{\text{Reported Trout Cod}}.$$

The misidentification and imprecision rates can be used for different purposes. This study examined how often a fish was misidentified (as indicated by the misidentification rate), and the number of fish angled and kept owing to erroneous identification (from the imprecision rate).

To analyse the misidentification and imprecision rates, and their association with length and legal status, logistic models for each rate and each species were constructed, one using fish length and the other using the legal Murray cod size limit (whether the fish could be kept, based on the legal take regulations for Murray cod at the time of angler catch). The legal size in the State of Victoria at the time of writing is 55–75 cm. The eight models were constructed in the statistical program R (R Core Team, 2016). Model selection between the pairs of models was conducted using Akaike information criteria (AIC). If the models had a difference in AIC of at least 4, the model with the smaller AIC value was considered the preferred model (Burnham & Anderson, 2010).

TABLE 2 Summary of recreational angler identifications of tagged individuals

		Reported by recreational anglers				
		Golden perch	Murray cod	Silver perch	Trout cod	Total
True species	Golden perch	924	26	11	5	966
	Murray cod	4	1778	1	37	1820
	Silver perch	2	6	63	1	72
	Trout cod	5	107	1	351	464
	Total	935	1917	76	394	3322

3 | RESULTS

Most of the 3322 tagged fish (including 1917 Murray cod and 394 trout cod) that had been reported by anglers were identified correctly (Table 2). Only 6.2% (95% confidence interval, 95% CI, 5.4–7.1%) of fish were misidentified (Table 3). The overall misidentification rate for trout cod was higher, however, with approximately a quarter of trout cod misidentified (95% CI 20.6–28.4%), with most errors (95%) being the misidentification of trout cod as Murray cod (Table 3).

The length of a trout cod affects the rate at which they are misidentified as Murray cod by recreational fishers (Figure 3). The trout cod misclassification model using length (the preferred model, with an AIC value smaller by 6.1 than that using legal size) shows that the larger the trout cod, the more likely it is to be misidentified as a Murray cod (gradient = 0.31, $P = 0.0047$). For example, the probability of a 400-mm trout cod being misidentified as a Murray cod was 23.5% (95% CI 19.8–27.7%), compared with 40.2% (95% CI 27.5–54.3%) for a 650-mm trout cod (Figure 3).

TABLE 3 Summary of misclassification rate for the four species of interest

		95% confidence interval	
	Misclassification rate	Lower bound	Upper bound
Golden perch	4.3%	3.2%	5.8%
Murray cod	2.3%	1.7%	3.1%
Silver perch	12.5%	6.2%	21.4%
Trout cod	24.4%	20.6%	28.4%
Overall	6.2%	5.4%	7.1%

The length of a Murray cod affects the rate at which the fish are misidentified as trout cod by recreational fishers (Figure 4). The Murray cod misclassification model using length (the preferred model, with an AIC smaller by 17.2 than that using legal size) shows that the larger the Murray cod, the less likely it is to be misidentified as a trout cod (gradient = −0.74, $P << 0.0001$). For example, the probability of a 400-mm Murray cod being misidentified as a trout cod is 3.4% (95% CI 2.5–4.7%), compared with 0.6% (95% CI 0.3–1.2%) for a 650-mm Murray cod (Figure 4). For small (approximately 200 mm) cod (both Murray and trout), the misidentification rates are very similar, at 14.1% (95% CI 9.1–21.3%) for trout cod and 13.4% (95% CI 6.9–24.4%) for Murray cod (Figures 3 and 4).

The length of fish affects the imprecision rate for fish identified as Murray cod by anglers (Figure 5). The Murray cod imprecision model using length (the preferred model, with an AIC smaller by 34.0 than that using legal size) shows that the larger the fish identified as Murray cod, the less likely it is to have been a misidentified trout cod (gradient = −0.79, $P << 0.0001$). For example, the probability of a 400-mm fish identified as a Murray cod by anglers being a trout cod was 9.4% (95% CI 7.8–11.4%), compared with 1.4% (95% CI 0.9–2.3%) for a 650-mm fish (Figure 5).

The length of fish affects the imprecision rate for fish identified as trout cod by recreational anglers (Figure 6). The logistic regression model shows that the larger the fish identified as trout cod, the more likely it is to have been misidentified as a Murray cod (gradient = 0.4,

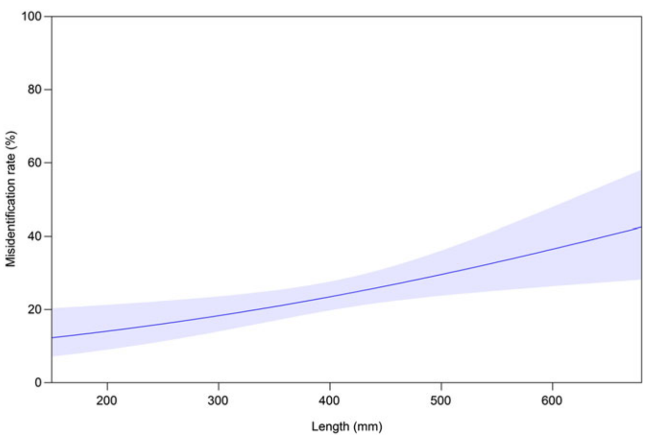

FIGURE 3 The average misidentification rate of trout cod as Murray cod as a function of fish length. The shaded area represents the 95% confidence interval

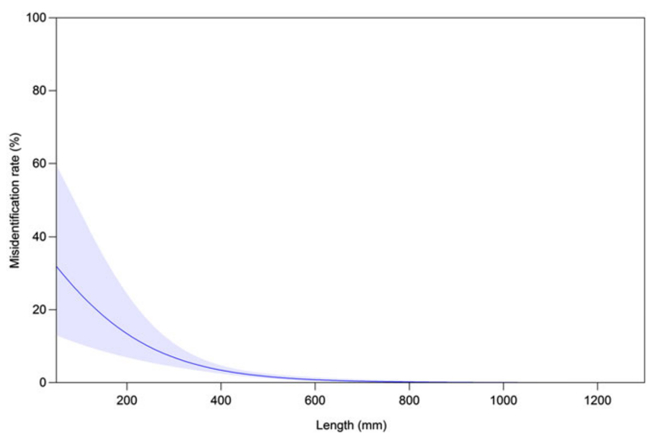

FIGURE 4 The average misidentification rate of Murray cod as trout cod as a function of fish length. The shaded area represents the 95% confidence interval

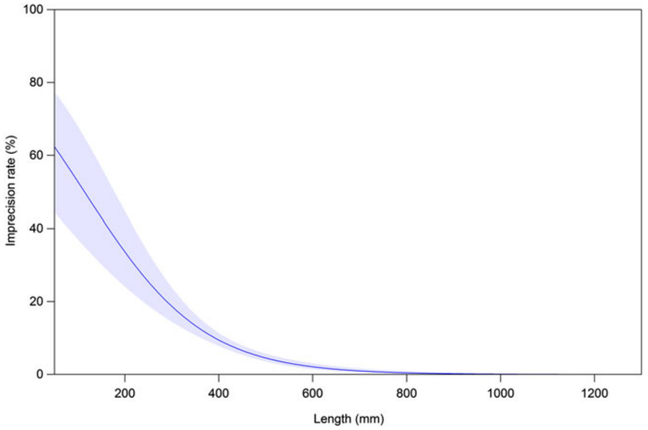

FIGURE 5 The probability that a fish identified as Murray cod by a recreational fisher is not a Murray cod as a function of fish length. The shaded area represents the 95% confidence interval

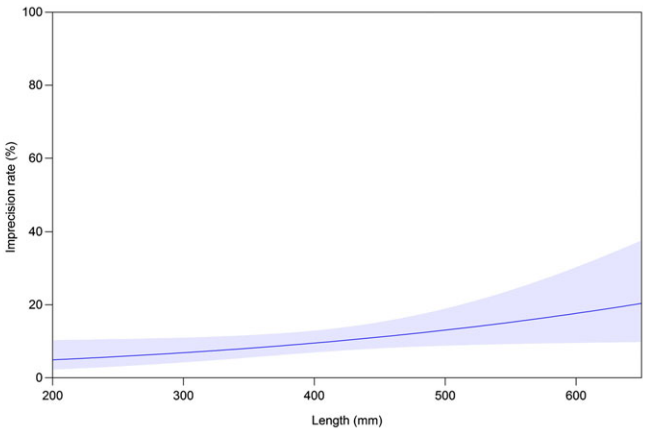

FIGURE 6 The probability that a fish identified as trout cod by a recreational fisher is not a trout cod as a function of fish length. The shaded area represents the 95% confidence interval

P = 0.0385). For example, the probability of a 400-mm fish identified as a trout cod by recreational fishers being a Murray cod is 9.5% (95% CI 7.0–13.0%), compared with 20.4% (95% CI 9.8–37.7%) for a 650-mm fish. The trout cod imprecision model using length (the equally preferred model, with an AIC larger by 0.4 than that using legal size) shows that the larger the fish identified as trout cod, the more likely it is to have been misidentified as a Murray cod (gradient = 0.35, P = 0.0385).

The trout cod imprecision model using legal size tells a similar story, that a fish identified as a trout cod is more likely to be a Murray cod if it is of legal size (for Murray cod). The imprecision rate jumped from 9% (95% CI 6–12%) for fish outside the legal size for Murray cod to 26% (95% CI 10–48%) for fish within the limit. That is, the expected imprecision rate almost tripled for trout cod if the fish was of legal length for Murray cod. Both models had very similar AIC values (the AIC value using legal size was smaller by 0.4), and therefore have similar levels of support.

For a small fish, the imprecision rates are very similar, at 9.4% (95% CI 7.8–11.4%) for fish identified as Murray cod and 9% (95% CI 6–12%) for fish identified as trout cod.

4 | DISCUSSION

There was a high rate of misidentification between the endangered trout cod and the popular angling species Murray cod in a large lowland river, and that the larger a trout cod was, the more likely it was to be misidentified. Length frequency for trout cod in this reach of river also shows a clear impact of angling pressure on trout cod, with very few trout cod being present within the legal bin size for Murray cod (Figure 7).

Although the recovery of trout cod from near extinction (Koehn et al., 2013; Lyon, Lintermans, & Koehn, 2018) has been a conservation success story, it is important that fishery managers properly understand all threatening processes if the species is to continue to expand into its historical range. The increasing human population in the south east of Australia is leading to the increased use of waterways by anglers, thereby increasing the probability of capture for this species. The study zone here is popular for recreational activities, such as camping and the associated recreational fishing and boating. As such, large numbers of less avid or not local anglers, who may only travel to the site to camp or fish once per year, frequent this area. The results of this study concur with those of Schmetterling and Long (1999), who found that less avid or occasional anglers were less able to correctly identify species with morphological similarities. Increasing urbanization globally could be expected to exacerbate this problem.

For the effective management of native species, anglers must be able to identify the species correctly, and unintentional harvest should be one threatening process to species recovery that can easily be alleviated through increased enforcement, education, and awareness (Schmetterling & Long, 1999). There is some evidence that the small proportion of large and older fish within a stock can produce disproportionately greater numbers of future cohorts (Berkeley, Chapman, & Sogard, 2004; Berkeley, Hixon, Larson, & Love, 2004; Birkeland & Dayton, 2005; Bobko & Berkeley, 2004; Hixon, Johnson, & Sogard, 2014), and that unintentional harvest, as seen here, may contribute towards earlier maturation ages and smaller sizes, and ultimately lower sustainable yields, and thereby reduce population resilience for this species (Olsen et al., 2004; Trippel, 1995).

Anglers can provide a powerful voice for conservation (Arlinghaus & Cooke, 2009); however, for this to occur, the angling community needs to be fully cognizant of the drivers of species decline and understand their role in leading recovery. Like bull trout in the Montana region of the USA, trout cod is one of several species subject to considerable historical and contemporary restoration investment (Koehn et al., 2013; US Fish and Wildlife Service, 2015). For trout cod recovery to succeed, managers and the angling community must continue to identify and remediate against threats such as those described here (Cooke et al., 2013). In south-east Australia, this could take the form of education campaigns targeting urban audiences through social media platforms, through increased investment in enforcement activities, and through continued collaboration between fishery and conservation managers with angling opinion leaders and lobby groups, who can work together to ensure threatened species are protected. Such actions are critical, not only for the continuing recovery of species, but also for anglers to maintain and increase their 'social licence' by championing a conservation agenda.

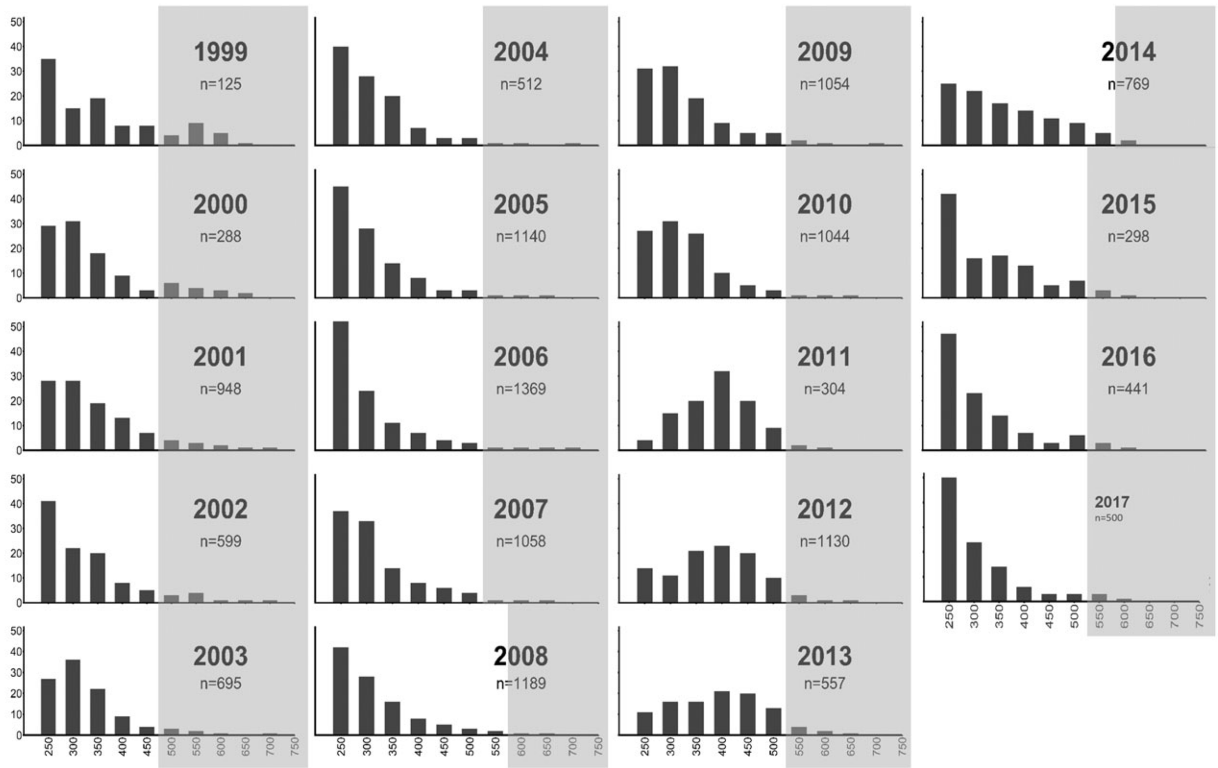

FIGURE 7 Length-frequency histogram for trout cod captured by electrofishing in the study reach between 2006 and 2013. The length bin refers to the groups of fish pooled by length (shown in 50-mm graduations). Grey shading indicates the fish available for harvest under fishery regulations (which changed over time)

Although this is a case study of a single species in a relatively isolated locality, there is a growing literature describing how increases in human interactions with animals can affect conservation outcomes. Jacquet and Pauly (2007) describe how another factor related to human population growth (increased appetite for seafood) is leading to overfishing in marine ecosystems, and in that example the authorities have directed considerable effort to public education around sustainable seafood practices. There are comparisons, too, with terrestrial systems, where more avid hunters were shown to be better able to identify waterfowl during field testing (Evrard, 1970).

In south-east Australia, the number of partnerships between anglers, conservationists, and governments to protect and restore threatened or ecologically sensitive fish fauna is growing (see, for instance, Barwick et al., 2014; Koehn et al., 2013). Fishery regulation is a powerful tool for managing biota, and for regulations to be used effectively, managers rely on anglers not only to be able to understand the regulations, but also to identify species. Where morphologically similar fish species coexist in popular angling streams, we propose that enhanced education (i.e. using social media platforms targeting urban fishing licence holders, and the installation of interpretive signage at campsites along this reach of river) and enforcement activities (including an increased frequency of licence and bag checks) be implemented (Cooke et al., 2013).

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