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Development of resources to promote best practice in the humane dispatch of finfish caught by recreational fishers

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Abstract Dispatch of finfish using the ikijime method (also known as ikejime or brain spiking) is the fastest and most humane way to kill fish. However, fish brains are small and vary in location between species groups. Without guidance, recreational fishers can find it difficult to pith the brain of a live fish accurately, potentially resulting in unnecessary stress. A lack of information on how to perform ikijime was considered a barrier to the widespread uptake of this method. This project filled the information gap by developing resources that provide accurate information on the ikijime procedure and pinpoint the location of the brain of fish commonly captured by recreational fishers. To assist with communicating this information to recreational fishers and the broader community, a new website www.ikijime.com was developed, together with the Ikijime Tool series of phone apps, which provide access to interactive photograph/radiograph overlays revealing the brain location of 100 species of fish from 38 families. These resources raise awareness of fish welfare issues and improve the ability of recreational fishers to dispatch fish humanely using best practice methods.

KEYWORDS: best practice, fish welfare, humane dispatch, ikijime, internet, technology.

Introduction

Recreational fishing is a popular pastime in Australia that imparts significant socio-economic benefits to the Australian lifestyle and economy. Each year recreational fishers interact with large numbers of wild finfish, a large proportion of which are released (McLeay *et al.* 2002). However, over 60 million finfish per annum are harvested and retained (Henry & Lyle 2003). Fishing is one of several factors that can influence the welfare of finfish and other aquatic animals in wild fisheries (Diggles *et al.* 2011), and in recent times, there has been increased interest in the welfare of fishes caught in wild capture fisheries (Hastein *et al.* 2005; Davie & Kopf 2006; Cooke & Sneddon 2007; Diggles *et al.* 2011). While the science of whether fish can experience pain remains highly uncertain (Rose 2007; Browman & Skiftesvik 2011; Key 2014; Rose *et al.* 2014), this does not preclude consideration of their welfare, as the fact that fish can experience stress when subject to unfavourable conditions is well documented and can be measured using functional criteria (Arlinghaus *et al.* 2009; Diggles *et al.* 2011).

The basic principles of humane slaughter remain similar for all animal species, being: rapid stunning without avoidable stress, followed by death as assessed by loss of brain function without recovery (Southgate & Wall 2001; Davie & Kopf 2006). Finfish can be slaughtered using a wide range of methods (reviewed by Southgate & Wall 2001; Robb & Kestin 2002; Robb 2008). The methods available to recreational fishers for dispatch of the finfish they harvest include asphyxiation in air or water, exsanguination (bleeding out), hypothermia by placement on ice or immersion in iced water/ice slurry, shooting with guns, spearguns or bow and arrow, or rendering fish insensible by physical damage resulting from percussive stunning, cervical dislocation or brain spiking (also known as pithing or ikijime) (Poli *et al.* 2005; Davie & Kopf 2006; Cooke & Sneddon 2007; Diggles *et al.* 2011). Other methods that are sometimes used to dispatch finfish in commercial aquaculture or for scientific purposes include electrocution, exposure to gases such as CO_2 or nitrogen, injection with barbiturates, and sedation or overdose with chemical anaesthetics (Robb *et al.* 2002; Lambooij *et al.* 2006, 2007; Meinertz *et al.* 2006; Roth *et al.* 2006; Wills *et al.* 2006; Bosworth *et al.* 2007; Matos *et al.* 2010; Rahmanifarah *et al.* 2011). However, these other methods are not available to recreational fishers due to cost, safety or logistical

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constraints, and/or legislation that prohibits the possession and use of some chemicals and anaesthetics due to concern about their misuse and/or chemical residues (Meinertz *et al.* 2006; AVMA 2013).

A review of the scientific literature regarding the acceptability of the various methods available to recreational fishers for killing finfish is summarised in Table 1. Historically, asphyxiation was probably the most common method of killing fish (Poli *et al.* 2005), but the time required for fish to die using this method is highly variable depending on species, temperature and whether fish are held in water or air (Robb & Kestin 2002). Asphyxiation in water generally results in a prolonged death, especially when air or water temperatures are cooler (Southgate & Wall 2001; Poli *et al.* 2005; Acerete *et al.* 2009), while air exposure is extremely aversive and stressful to most fish (Kestin *et al.* 1991; Robb & Kestin 2002). For these reasons, asphyxiation in air or water is not generally considered humane methods for dispatch of finfish (Table 1).

Exsanguination (bleeding out) without stunning is also used to kill fish (Robb & Kestin 2002), but it is a relatively slow method. For example, Atlantic salmon, *Salmo salar* L., killed by exsanguination take between 4.5 and 15 min to lose brain function depending on water temperature (Erikson *et al.* 1999; Robb *et al.* 2000). Exsanguination without stunning is therefore not generally considered a humane method for killing fish (Table 1), and instead bleeding fish after stunning is encouraged as it is likely to improve welfare without compromising quality (Robb & Kestin 2002; Davie & Kopf 2006; Table 1).

Table 1. Summary of results from the literature review regarding the humane acceptability of the various methods of killing fish available to recreational fishers

Generally considered acceptable and humane	May be acceptable and humane for certain species and/or under certain conditions	Generally considered not acceptable if applied to unstunned fish
Shooting	Hypothermia in ice slurry‡	Asphyxiation in air
Percussive stunning*	Decapitation†	Asphyxiation in water
Brain spiking/ikijime†	Cervical dislocation†	Exsanguination/ bleeding out†

*Should be followed by ikijime, bleeding or decapitation/cervical dislocation to prevent recovery.

†Ideally used on fish stunned first by percussive stunning.

‡For best quality and welfare, large fish (>500 g) and/or fish taken from water cooler than around 20 °C should be stunned and/or ikijimed prior to placement in ice slurry.

Hypothermia in an ice slurry appears a humane method for killing some species of fish, especially those with smaller body sizes taken from warm (>20 °C) water (Wilson *et al.* 2009; Blessing *et al.* 2010; AVMA 2013). Thermal shock can reduce the time to loss of brain function and death without avoidable stress, provided the temperature differential is large and the fish is small (Stevens & Fry 1970). Indeed, many of the physiochemical product quality indices of fish killed in ice slurry can equal those obtained using faster and the so-called more humane killing methods such as percussive stunning, electrocution or brain spiking (Poli *et al.* 2005; Scherer *et al.* 2006; Giuffrida *et al.* 2007). However, the method is not considered universally suitable (Table 1) as it may not be effective for large fish >500 g (Stevens & Fry 1970; Stevens & Sutterlin 1979), nor cold water adapted fish species, such as cyprinids and salmonids acclimated at water temperatures below around 15 °C (Foss *et al.* 2012; AVMA 2013). Decapitation and cervical dislocation are other killing methods that also produce variable results in fish (Table 1). For some species, death occurs immediately after cervical dislocation resulting in minimal stress (B.K. Diggles, personal observations); however, for others, for example eels, death may not be immediate after decapitation or cervical dislocation unless both the brain and spinal cord are subsequently pithed (Verheijen & Flight 1997; Robb & Kestin 2002). AVMA 2013 recommended that fishes can be euthanised by decapitation, but ideally only after being stunned first.

Of the three killing methods generally considered acceptable and humane (Table 1), shooting of finfish can be performed by recreational fishers using guns, spearguns or bow and arrow. Shooting can result in immediate death if the shot is accurate (to the head), and for this reason the method is used to kill large, high-value fish quickly to prevent damage and stress during escape attempts (Robb & Kestin 2002). However, shooting of finfish with rifles or handguns is not generally performed by recreational fishers in Australia (or elsewhere), due to safety reasons as well as strict gun control laws in some countries. Percussive stunning is a process whereby fish are killed by a blow (or blows) delivered to the head using a club (priest) or similar (Robb & Kestin 2002; Poli *et al.* 2005). When the blow is correctly applied and is of adequate force, all movement and brain function is immediately lost (Kestin *et al.* 1995; Marx *et al.* 1997; Robb *et al.* 2000; Lambooij *et al.* 2002; Morzel *et al.* 2002). If applied incorrectly, however, insensibility may not be immediate (Kestin *et al.* 1995; Robb *et al.* 2000), or the fish may recover (Davie & Kopf 2006). This is why some authors recommend that percussive stunning should always be followed by pithing, bleeding out or decapitation (Davie & Kopf 2006). Because less accuracy is required to stun the fish due to

brain injury when using a club, percussive stunning requires relatively little skill to perform.

Brain spiking (also known as pithing or ikijime – that latter being a Japanese term denoting 'live killing', or 'to terminate while alive') is the most rapid method of dispatching fish available to recreational fishers in the field (Davie & Kopf 2006). Administered accurately, brain spiking can be a one-step process that results in the lowest levels of stress and maximal product quality in slaughtered finfish compared with all other methods of dispatch (Boyd *et al.* 1984; Poli *et al.* 2005; Davie & Kopf 2006). Once the brain is destroyed, the fish is immediately killed (Lambooij *et al.* 2002), which drastically reduces stress, lactic acidosis, bruising and other undesirable changes that occur if the fish is left to die slowly in air, water or on ice (Boyd *et al.* 1984; Harada 1988; Poli *et al.* 2005). Brain spiking thus improves product quality by minimising pH drop due to lactic acid build-up, and also significantly delays the onset of rigour mortis, especially if the ikijimed fish is placed immediately on ice (Boyd *et al.* 1984; Harada 1988; Lowe *et al.* 1993).

However, the brains of fish are relatively small and a high level of skill and a certain amount of anatomical knowledge is needed to pith the brain of a live fish accurately (Lambooij *et al.* 2002; Poli *et al.* 2005). Further, effective restraint of the fish is an important prerequisite needed for accurate brain spiking (Lambooij *et al.* 2002); hence, the difficulty of this process may be amplified in some recreational fishing scenarios, such as at sea on small boats (Davie & Kopf 2006). For these reasons, it is possible to miss the small target point and the fish may become unnecessarily stressed during the procedure (Poli *et al.* 2005). Because of this, percussive stunning is often recommended prior to use of the ikijime method, as this ensures the stunned fish are easier to restrain during the spiking process (Davie & Kopf 2006).

In Australia's National Code of Practice for Recreational and Sport Fishing, fishers are encouraged to '*dispatch fish immediately with a firm tap on the head with a suitable blunt object or by pithing*' (Recfish Australia 2008). This advice is consistent with scientific advice regarding best practice for humane dispatch of finfish; however, while dispatch of fish by percussive stunning is a straightforward process requiring relatively little skill, this is not the case with the brain spiking technique. Observations of anglers in the field (B. K. Diggles, personal observations) show that without guidance, many recreational fishers (particularly inexperienced ones) find it difficult to pith accurately the brain of a live fish, and the fish may become unnecessarily stressed during this process. A lack of information on how to perform ikijime was considered a barrier to the wider uptake of this best practice method of humane dispatch of finfish. Consequently, a project was undertaken to fill the information gap by developing resources that provide recreational fishers with accurate information on how to perform the ikijime method.

Methods

A survey of Australian recreational fishers was undertaken in the Fishing World magazine website (http://www.fishingworld.com.au/news/humane-dispatch-survey) over 100 days from 8 February to 18 May 2012, to gather information on fisher behaviour in relation to the methods used to kill finfish. The survey questionnaire was designed to obtain basic information on recreational fisher behaviour relating to whether they killed finfish caught during the course of their activities, and if so, what methods they used. The survey questionnaire consisted of three questions. Question three sought to determine which dispatch methods were used, as follows:

Question 1. Do you kill any of the fish you catch?
i Yes
ii No, I release everything I catch
Question 2. Do you use any of the fish you catch as live bait?
i Yes
ii No, I only use lures
iii No, I only use dead bait
iv No, I only use lures or dead bait.
Question 3. If you take fish to eat, how do you currently kill them? Do you:
i Let the fish die in the air or in a bucket of water (asphyxiation)?
ii Kill the fish by placing it in an ice slurry (chilling)?
iii Kill the fish by bleeding it out?
iv Kill the fish with a knock to the head (stunning) or decapitation?
v Kill the fish using the brain spiking (ikijime) method?
vi Use a combination of 3, and/or 4 and/or 5 followed by 2?
vii Not applicable – I do not take fish to eat.

The survey was designed so that only one response could be submitted from each IP address, to discourage the submission of multiple responses from one person.

At the same time, morphological investigations were undertaken to pinpoint the brain location of freshwater and marine finfish most commonly encountered by recreational fishers throughout Australia, New Zealand and the Asia/Pacific region. Fish were captured, killed by overdose of anaesthetic (Aqui-S Ltd, Lower Hutt, New Zealand, 0.3 mL 10 L^{-1}) then their external features were photographed in lateral and/or dorsal view with a digital camera. The fish were then frozen before being X-rayed in the lat-

eral and/or vertical axis. The head of each fish was then dissected to pinpoint exactly the brain location for each species sampled. Photograph/radiograph overlays were then performed electronically using paint.net software (version 3.5.10) Copyright (C) dotPDN LLC and Rick Brewster, and the brain locations were determined before being superimposed graphically (as a white oval) over the colour photographs of the exterior of each fish, showing the location of the brain against external landmarks.

All activities related to capture and killing of fish that were undertaken during the course of this study were carried out with ethics approval under AEC project number CA 2011/08/537.

Results

Survey results

The survey was completed by 450 respondents. For Question three, which related to dispatch methods used, each respondent was asked to select one of 7 options to best describe how they killed the fish they caught. The seventh option 'not applicable' was included for fishers who released all of their catch, and this was selected by 3.5% of respondents. The majority (78.3%) of the remaining 96.5% of respondents used best practice methods for killing their catch. These included percussive stunning (9.1%), ikijime (8.5%), ice slurry (8.5%) or a combination of either bleeding, percussive stunning or ikijime followed by ice slurry (52.2%). Only 12.7% of respondents indicated that they killed their fish by exsanguination alone, while 5.5% indicated that they killed their fish by asphyxiation.

Morphological information

Morphological information for brain location was obtained using X-ray and dissection for over 80 species of finfish from 33 families of finfish most commonly encountered by anglers throughout Australia, New Zealand and the Asia/Pacific region. Upon public release of this information on the www.ikijime.com website, recreational anglers from North and South America provided brain location information (based on photos of dissections only) for a small number of additional fish species commonly captured in these countries, such that as of 1 November 2014, brain location information had been obtained for 100 species of finfish from 38 families.

Extension of brain location information via website and phone apps

Initial attempts to extend to anglers in Australia instructional information on the ikijime technique as well as the brain location information centred around development of hard copy A4-sized pamphlets. These displayed brain location information in colour photographs of the exterior of a limited number of fish species. The 24 species depicted in pamphlets were selected because they were those most commonly caught by recreational anglers in Australia. The relevant brain locations were superimposed graphically onto the colour photographs of each fish species, and the pamphlets were organised into three versions that contained information for popular species commonly encountered by fishers in freshwater, estuarine and offshore fishing locations. A total of 150 000 pamphlets were printed and distributed to anglers via fishing tackle shops and mailouts in national fishing magazines. However, the utility of delivery of the information via hard copy pamphlets was severely constrained by limitations in space, such that information for only 24 of the most popular species of fish could be presented in this manner (maximum eight species per pamphlet type). Given that <25% of the database could be presented in the traditional printed manner, and because it was determined that the electronic photograph/radiograph overlays themselves were highly useful educational resources (Fig. 1), a decision was made to deliver the information to recreational fishers electronically. The most appropriate way of presenting this information to recreational fishers as well as the wider community was considered to be development of instructional videos, as well as placement of the photograph/radiograph illustrations onto a dedicated website (www.ikijime.com). The instructional videos were developed and uploaded on to Youtube, while the website was developed with interactive photograph/radiograph overlay functions that allow users to view the fish brain location in X-ray format, exterior colour photo format (Fig. 1) or composite images containing a combination of the two images (Fig. 2) using a toggle/slider function. The website also required development of a 'fish finder' search function allowing users to search the database for fish by habitat (freshwater, estuary or offshore), fish group (common name) and then by common name for individual fish species (if required). An 'Advanced Search' function was also incorporated which allowed the database to be searched using taxonomic criteria searching firstly by fish family, then genus and species.

Development of the website granted recreational anglers and the wider community online access to brain location information for all 100 species of finfish from 38 families, representing in excess of a 400% increase in information availability compared with the traditional hard copy pamphlet method. The development of the website also opened the way to utilisation of even more technology in the form of development of phone

Figure 1. Electronic overlays from www.ikijime.com showing how sliding the toggle (red bar) from the left to the right switches between an external full colour photograph (upper) and a radiograph (lower) of a bluefish (*Pomatomus saltatrix* (Linnaeus 1766)). The brain location is superimposed graphically on the colour photograph as a white oval.

applications that allow recreational anglers and other users to access the brain location database while they are actually fishing (or otherwise away from their desktop computer). The Ikijime Tool series of phone apps use the same fish search and interactive photograph/radiograph overlay functions as the website and were developed for both Apple IPhone and Android operating systems. The Ikijime Tool Lite version of the app is a free version that allows limited access to the online database. This free version of the app ensures that there is no 'barrier to entry' ensuring that all anglers have access to the humane dispatch and fish welfare information held in the website, while limiting download access to encourage trial users to purchase the other versions of the app (to aid cost recovery). The Ikijime Tool app provides unlimited access to the online database, and like

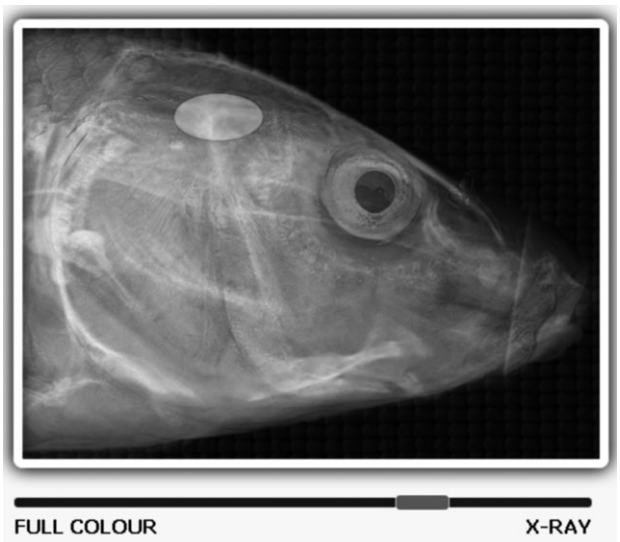

Figure 2. Composite electronic overlay from www.ikijime.com showing the brain location of a European carp (*Cyprinus carpio* Linnaeus 1758) using a combination of external and internal features by toggling the slide (red bar) in between the full colour and X-ray images. The brain location is visible as a white oval.

the Lite version, it requires an internet or phone signal to access the website database. By contrast, the Ikijime Tool Extreme version of the app contains its own database, and thus retains full functionality even in remote places out of phone or internet range.

Discussion

Unlike in commercial fishing or aquaculture, finfish caught by recreational fishers are typically captured singly or in small numbers at any one time. This means that recreational fishers who are educated regarding best practice methods for humane killing of finfish are well positioned to ensure that every fish chosen for harvest can be slaughtered quickly using best practice methods for humane killing (Diggles *et al.* 2011). While asphyxiation is traditionally used for captured fish (Poli *et al.* 2005) and remains commonly used by many fishers around the world (Diggles *et al.* 2011), the survey conducted during this study indicated that only a minority of Australian recreational fishers (≈6%) continue to use this method. The survey also found only a relatively small number of fishers (≈13%) used exsanguination alone as a method of dispatching their fish. This result may be in response to increased education in recent years in both Australia (Recfish Australia 2008) and overseas (Cooke & Sneddon 2007; EIFAC 2008) that may have encouraged recreational fishers to use more humane slaughter methods such as ice slurrys (with or without exsanguination), cerebral percussion and ikijime.

The use of these methods alone, or in combination, is not only generally considered to be best practice and more humane (Davie & Kopf 2006), they have the added benefit of improvement in product quality (Poli *et al.* 2005).

Based on review of the scientific literature, the recommendations of the Australian National Code of Practice (Recfish Australia 2008) can still be endorsed as representing best practice, in that they encourage recreational fishers to use percussive stunning (to assist in restraining the fish), and/or ikijime, to dispatch fish. The results of the survey suggest that around 78% of Australian fishers used best practice methods for killing their catch, and that the majority (≈52%) of these used a combination of either bleeding, percussive stunning or ikijime followed by ice slurry. Regardless of whether the fish has been previously stunned or not, the ikijime method of brain spiking (if administered accurately), can be a one-step process that results in the lowest levels of stress and maximal product quality in slaughtered finfish compared with all other methods of dispatch (Boyd *et al.* 1984; Harada 1988; Poli *et al.* 2005; Davie & Kopf 2006). Furthermore, the ikijime method is the only best practice method of humane killing available to spear fishers while they are underwater if they fail to kill their quarry immediately by shooting with a 'head shot'. However, despite all of the benefits of the ikijime technique, its effectiveness as a humane method of dispatch depends on the ability of the fisher to firstly restrain the fish and accurately locate the brain, and then determine the best method of penetrating the cranial cavity with a suitable implement to destroy the brain quickly and effectively.

Feedback from recreational fishers in Australia (B. K. Diggles, unpublished) has indicated that the advice on the ikijime method as well as provision of the brain location information that has been made available via the www.ikijime.com website and phone apps has demystified the ikijime technique, and increased the likelihood of recreational fishers using the method through reducing fear of missing a relatively small target with the spiking implement. Indeed, the website database and phone apps are available worldwide, user friendly and can accommodate large quantities of data, opening the way for this concept to be extended by incorporating more species of fish into the database from other regions including North and South America, Europe and Asia. Nevertheless, in the future additional follow-up surveys of a larger sample of the recreational fishing community in Australia will be required to determine whether provision of the 'how to' information on the ikijime method has encouraged wider use of brain spiking as a method of humane dispatch in Australia.

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