LITERATURE REVIEW - BEST PRACTICE IN HUMANE DISPATCH OF FINFISH CAUGHT BY RECREATIONAL FISHERS

DIGSFISH SERVICES

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Summary

Recreational fishing is a highly popular pastime throughout Australia which imparts significant socio-economic benefits. Recreational fishers in Australia harvest over 60 million finfish each year, and whilst a wide range of factors influence the welfare of wild finfish, concerns have been raised regarding the welfare of fishes caught and retained in recreational fisheries. The science of whether fish can experience pain remains very uncertain, but this does not preclude consideration of their welfare, especially as their responses to stressors are well known and can be measured using functional criteria. This paper critically reviews the peer reviewed scientific literature that has examined the range of methods available to recreational fishers to dispatch finfish, to determine which of these are most likely to represent best practice for humane dispatch of finfish taken by recreational fishers in Australia.

Historically asphyxiation was probably the most common method used by recreational fishers to kill finfish, however scientific evidence suggests that asphyxiation in air or in water at ambient temperatures is highly stressful and results in poor welfare outcomes for finfish, as well as reduced product quality. Our survey suggested that the asphyxiation method remains used only by a minority of recreational fishers. Hypothermia in an ice slurry without stunning does not result in elevated stress levels in many fish species, however this method may not be suitable for large bodied and/or cold adapted finfish, due to the extended periods of time that can pass before death occurs. However, for smaller finfish (and especially those adapted to tropical and warm temperate environments), thermal shock can drastically shorten the time to loss of brain function and death to a few seconds, meaning that immersion in an ice slurry should be considered an acceptably humane method of killing at least some species of fishes. Exanguination (bleeding out) alone is stressful and prolonged and therefore not an ideal method of killing finfish, however bleeding finfish after stunning is likely to improve welfare without compromising quality, hence most authorities consider that finfish should only be bled after the fish has been stunned or dispatched using other methods such as brain spiking or percussive stunning.

Decapitation or cervical dislocation can result in immediate death (and therefore minimal stress) in some species of finfish, however for other fish species death may not be immediate using these methods. Because of this, decapitation or cervical dislocation is generally recommended for use only on fish rendered unconscious via other methods such as percussive stunning. Spearfishers or fishers with access to guns or bow and arrow can inflict instantaneous death of fish if a "kill shot" is performed (i.e. one that kills the fish immediately by penetrating vital organs or the brain), but if the fish survives the shot they should be killed as quickly as possible using other methods such as percussive stunning or brain spiking. In the 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 review finds that these recommendations still represent best practice for rapid and humane killing of finfish. Percussive stunning is probably the easiest method for recreational fishers to use, while brain spiking (also known as pithing or iki-jime) requires higher skill levels, but can be a one-step process which results in the lowest levels of stress and maximal product quality. However, because the brains of fish are not large, it is possible to miss the small target, which is why educational materials are needed to provide the relevant anatomical and "how to" information to allow recreational fishers to develop the confidence to use the iki-jime method more widely.

1.0 Introduction

Recreational fishing is a very popular pastime throughout Australia which imparts significant socio-economic benefits to the Australian lifestyle and economy. Each year recreational fishers interact with large numbers of wild finfish and shellfish, a large proportion of which are released (McLeay et al. 2002), however over 60 million finfish per annum are harvested and retained (Henry and Lyle 2003). Fishing is one of several factors that can influence the welfare of wild finfish and other aquatic animals in wild fisheries (Diggles et al. 2011a, 2011b), and in recent times concerns have been raised regarding the welfare of fishes caught in wild capture fisheries (Hastein et al. 2005, Davie and Kopf 2006, Cooke and Sneddon 2007, Mood 2010, Diggles et al. 2011a, 2011b). In Australia, the recreational fishing industry has demonstrated its continued commitment to improvement of welfare outcomes for finfish through many environmental initiatives that aim to protect and restore fish habitat[1,2] (NSW Department of Primary Industries 2009), as well as development of world leading initiatives such as the National Strategy for the Survival of Released Line Caught Fish (McLeay et al. 2002), the NEATFish environmental standard for fishing tournaments (Sawynok et al. 2008, www.neatfish.com), and the National Code of Practice for Recreational and Sport Fishing (Recfish Australia 2008).

While the science of whether fish can experience pain remains highly uncertain (Rose 2007, Browman et al. 2011, Rose et al. submitted) 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 their responses to these stressors can be measured using functional criteria (Diggles et al. 2011a, 2011b). Thus, the basic principles of humane slaughter remain similar for all animal species, being: rapid loss of consciousness without avoidable stress, followed by death as assessed by loss of brain function without regaining consciousness (Southgate and Wall 2001, Davie and Kopf 2006). In the 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 the universal principles of humane slaughter as well as the guidelines provided by the National Consultative Committee on Animal Welfare (NCCAW), which suggest "*Captured fish which are to be kept, must be killed as soon as possible, either by a blow to the head or by using the sharp end of a knife to destroy the brain. Prompt killing protects the welfare of the fish and improves the quality of the product*" (http://www.daff.gov.au/animal-plant-health/welfare/nccaw/guidelines/fishing).

Finfish can be killed using a wide range of methods (reviewed by Southgate and Wall 2001, Robb and Kestin 2002, Yue 2008, Robb 2008). There are several methods available to recreational fishers for dispatch of the finfish they harvest, including 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 iki-jime) (Davie and Kopf 2006, Cooke and Sneddon 2007, Diggles et al. 2011a). Sometimes combinations of two or more of

[1] http://www.fishhabitatnetwork.com.au/faqs/
[2] http://www.dpi.nsw.gov.au/fisheries/habitat/rehabilitating/fishers

these methods may be used (e.g. percussive stunning followed by exsanguination in conjunction with hypothermia in an ice slurry).

Other methods that are sometimes used to dispatch finfish in commercial aquaculture or for scientific purposes include electrocution (Robb et al. 2002a, 2002b, Robb and Roth 2003, Lambooij et al. 2006, 2007, Soto et al. 2006, Lines and Spence 2012), exposure to gases such as CO_2 or nitrogen (Roth et al. 2006, Wills et al. 2006, Erikson et al. 2006, Robb 2008, Acerete et al. 2009), injection with barbiturates, and sedation or overdose with chemical anaesthetics including tricaine methane sulfonate (MS 222), benzocaine hydrochloride, 2-phenoxyethanol, metomidate; clove oil and Aqui-S (Isoeugenol) (Meinertz et al. 2006, AVMA 2007, Bosworth et al. 2007, Matos et al. 2010, Rahmanifarah et al. 2011). These other methods are not available to recreational fishers due to cost, safety or logistical constraints (electrocution, nitrogen, CO_2) (Davie and Kopf 2006), and/or legislation that prohibits the possession and use of some chemical and anaesthetics due to concern about chemical residues (Meinertz et al. 2006) and/or their misuse. Because of this, electrocution, exposure to gases, barbiturates and anaesthetics will not be reviewed further here. The remaining methods of dispatch of finfish that are available to recreational fishers will be critically reviewed in order to determine which of these are most likely to represent best practice for humane dispatch of finfish taken by recreational fishers in Australia.

2.0 Methods

A review of the peer reviewed scientific literature, and selected other literature relating to humane dispatch of finfish, was conducted using several databases and abstracting engines, such as Scirius, Scopus, ISI Web of Knowledge, Cambridge Scientific Abstracts, Medline, and IngentaConnect as well as internet databases such as Google and Google Scholar using the search terms fish and finfish together with the terms welfare, dispatch, slaughter, stun, euthanasia, euthanase, brain spike, and iki-jime. A survey of Australian recreational fishers was also conducted in the Fishing World magazine website over 100 days from 8 February to 18 May 2012, to gather baseline information on their behaviour in relation to the methods they used to kill finfish. The results from this process are presented below.

3.0 Results

3.1 Asphyxiation

Asphyxiation historically was probably the most common method of killing fish (Poli et al. 2005), with the time required for fish to die using this method being highly variable depending on the fish species, the temperature, and whether fish were being held in water or air (Robb and Kestin 2002). The vast majority of fish are ectotherms and their metabolic rate is temperature-dependent, meaning their oxygen requirements are reduced when temperatures are lower, hence the process of asphyxiation will generally be prolonged whenever air or water temperatures are cooler (Southgate and Wall 2001, Poli et al. 2005).

3.1.1 In air

Asphyxiation in air involves the removal of fish from the water. When fish are taken out of the water, their gill lamellae collapse, greatly reducing the area for oxygen exchange, resulting in anoxia and eventual mortality (Southgate and Wall 2001). The time to death in air depends on the identity of the fish species as well as the ambient temperature; for example, rainbow trout die after 2.6 minutes at 20ºC, 3 minutes at 14ºC, and 9.6 minutes at 2ºC (Kestin et al. 1991). Brain death in Atlantic salmon (*Salmo salar*) was shown to occur after two to three minutes at 20°C, but at 2°C this was prolonged to 14 minutes (Robb et al. 2000). In contrast, eels (*Anguilla* spp.) can survive for a very long time (>24 hours) out of the water, especially in moist conditions (Robb and Kestin 2002, Poli et al. 2005), and European carp (*Cyprinus carpio*) are also very tolerant of hypoxia (Hastein et al. 2005). Indeed, Rahmanifarah et al. (2011) found that it took nearly 5 hours for opercular movements in carp to cease once they were removed from 23°C water. Mugnier et al. (1998) found that air exposure for up to 4 minutes induced no biochemical stress response in juvenile turbot (*Psetta maxima*), possibly because turbot obtain only 70% of their oxygen requirement through the gills, with the remaining 30% exchanged through the skin (Morzel et al. 2002).

Nevertheless, asphyxiation in air is extremely aversive to most fish species, which usually show violent escape behaviors accompanied by maximum stress responses (Robb and Kestin 2002). Because of this, several authorities including the Australian and New Zealand Council for the care of animals in research and teaching (ANZCCART), American Veterinary Medical Association (AVMA), the European Food Safety Authority (EFSA) and the Farm Animal Welfare Council (FAWC) in the UK do not consider asphyxiation by removal from the water as a humane method of killing fish (FAWC 1996, Reilly 2001, EFSA 2004, AVMA 2007). Furthermore, these escape behaviours in conjunction with the anoxia from air exposure induce several physiological and biochemical changes in the fish, including elevated blood lactate, cortisol and glucose levels, decreased muscle pH and adenosine triphosphate (ATP), as well as increased risk of muscle damage, haemorrhage and bruising and earlier onset of rigor mortis (Poli et al. 2005). Rigor mortis is the contraction of muscle fibres as a result of calcium leakage, in the absence of ATP (Adenosine Triphosphate), which is the muscles energy source required to contract and relax the muscle (Poli et al. 2005, New Zealand Institute of Chemistry 2008). These data demonstrate that asphyxiation is stressful and results in undesirable physiochemical changes that can significantly reduce the quality and shelflife of the resulting product (Harada 1988, Poli et al. 2005, Poli 2009).

3.1.2 In water at ambient temperatures

Another method of asphyxiation of fish is by retaining them in a container of non-aerated water held at ambient temperature (For information on the fate of fish in water chilled below ambient temperatures, see Section 3.2). Under these circumstances when no water exchange is permitted at ambient temperatures, death of the fish eventually occurs due to asphyxiation as a result of a reduction in the oxygen content of the water, possibly in conjunction with buildup of toxic metabolites such as ammonia. Experimental attempts have been made to kill fish in water from which all the oxygen has been removed, either by degassing the water or by displacing the oxygen with an inert gas such as nitrogen or argon (Robb and Kestin 2002, Wills et al. 2006, Erikson et al. 2006). These studies have shown that it is difficult to remove sufficient oxygen from the water for death to occur in a short period of time (Kestin et al. 1997). Even if inert gases were available to recreational fishers, maintenance of the anoxic water is also difficult, because fish activity and the process of adding the fish enable atmospheric air to become dissolved in the water. In these studies, the fish showed aversive reactions during induction of insensibility; however, these were less severe than those shown by fish killed by CO_2 narcosis (Kestin et al. 1997). Time to death for fish allowed to asphyxiate in water at ambient temperatures can be much prolonged over that if fish asphyxiated in air, especially at lower water temperatures. For example, Acerete et al. (2009) found that European sea bass (*Dicentrarchus labrax*) took much longer (128 minutes) to be killed by asphyxiation in a bucket of water compared to fish exposed to CO_2 narcosis (16 minutes) and hypothermia in an ice slurry (34 minutes). The poor welfare of the seabass asphyxiated in water was demonstrated by the fact that they exhibited significantly elevated blood plasma glucose levels compared to fish killed by hypothermia in an ice slurry or by exposure to CO_2 (Acerete et al. 2009). Other undesirable changes such as increased cortisol and lactate, reduced muscle pH and ATP, and early onset of rigor mortis, all of which demonstrate that asphyxiation in water at ambient temperature is highly stressful and significantly reduces the quality and shelflife of the resulting product (Poli et al. 2005, Poli 2009).

3.2 Hypothermia in ice slurry

Addition of ice to water at ratios of greater than or equal to 1:1 (ice:water) forms an ice slurry with water temperatures around -2°C to 2°C, with the final slurry temperature depending on the water temperature before addition of the ice, the quantity and temperature of the ice used and whether the slurry is made up with freshwater or seawater. In the absence of prior application of other killing methods, asphyxiation is the usual cause of death in fish placed in ice slurrys (Robb and Kestin 2002, Poli et al. 2005, Bagni et al. 2007). The metabolic rate of ectotherms such as fish is temperature-dependent, and their oxygen requirements are much reduced in colder water (Southgate and Wall 2001). This means that onset of asphyxiation in water tends to be delayed as water temperatures are reduced (Robb and Kestin 2002, Bagni et al. 2007). When large bodied temperate and/or cold water adapted fish are placed in an ice slurry, they are not normally stunned by the treatment, and hence they may subsequently retain brain function for some time until asphyxiation occurs (Robb and Kestin 2002, Ashley 2007). Indeed, up to 3 hours may be required before death in ice slurry for some cold adapted species such as salmonids (Southgate and Wall 2001), however Kestin et al. (1991) found that rainbow trout (*Oncorhynchus mykiss*) taken from 14°C water lost brain function after only 9.6 minutes in an ice slurry. In contrast, time to death of European sea bass acclimatised to 19.5°C once placed in an ice slurry was longer (34 minutes), but still much faster than that for European sea bass asphyxiated in a bucket of water at 19.5°C (128 minutes) (Acerete et al. 2009).

Wall (2001) and Davie and Kopf (2006) observe that fish species that are tolerant to hypoxia (e.g. catfish (Ictaluridae) and carp (Cyprinidae)) are likely to die more slowly than more active fish species such as salmonids and scombrids when placed in ice slurries. Indeed, Rahmanifarah et al. (2011) found that 1 kg European carp transferred from 23°C water into water chilled to 0.6-1.5°C took an average of 11 minutes to lose equilibrium and 33 minutes to become unresponsive to external stimuli. However, for some fish species, if the differential between the ambient temperature of the fish and the ice slurry is high, thermal shock can dramatically shorten the time to loss of brain function (Robb and Kestin 2002). This appears applicable particularly for smaller (< c. 500 g) tropical and warm temperate fish with low thermal inertia, and for these if the temperature differential is large enough (c. > 20-25°C), stunning can occur almost immediately upon placement in the ice slurry, and death can follow rapidly (Wilson et al. 2009, Blessing et al. 2010, B.K. Diggles, personal observations). Indeed, Poli et al. (2005) noted that studies by Bagni et al. (2002) and Zampacavallo et al. (2003) found that immersion in ice slurry did not appear particularly stressful to warm water Mediterranean species, such as sea bream (*Sparus aurata*) and European sea bass. Wilson et al. (2009) compared chilling and anesthesia (MS222) for euthanasia of zebrafish (*Danio rerio*) and found that time to death was longer (mean 53 seconds) and distress was greater for fish exposed to the anaesthetic, and that 4/23 fish recovered from anaethesia, compared to a mean time to death of 7 seconds with no recovery of fish in the chilling treatment when transferred from 28°C to 2°C, in the absence of ice crystal formation. They recommended use of chilled water for euthanasia of zebrafish in light of the faster time to death and fewer signs of distress (Wilson et al. 2009). Similarly, Blessing et al. (2010) found that bony bream (*Nematolosa erebi*) up to 13.5 cm length taken from water at 25.5°C and placed in an ice slurry (1:1 ice:freshwater at 0-2°C), took on average 0.1 min to lose equilibrium and 0.34 minutes to die, significantly faster than bony bream anaesthetized with 100 mg/L benzocaine (mean 2 minutes to lose equilibrium and mean time to death 3.6 minutes).

The body temperature of fish placed in an ice slurry at c. 0-2°C decreases in an logarithmic manner depending on the fishes initial temperature and body mass (Stevens and Fry 1970, Skjervold et al. 2002, Morzel et al. 2002), with the majority of heat being lost through the body wall and fins (Stevens and Sutterlin 1976, Crawshaw 1979). In small to medium sized fish placed in water of different temperatures, the rate of change of body temperature is rapid, ranging from around 2°C body temperature change per °C water temperature differential/min (°/min per °difference) for fish less than 10 grams body weight, to around 0.2°/min per °difference for fish around 200 grams (Stevens and Fry 1970). These data suggest that stunning due to temperature drop in an ice slurry will be most effective for smaller fish held at high ambient water temperatures (>20-25°C), and that there is likely to be an upper limit to the size of fish which can be rapidly stunned in an ice slurry. For example, Morzel et al. (2002) found it took 25 and 55 minutes for the body temperature of 500 gram turbot (*Psetta maxima*) to decrease from an initial 16°C to 5°C and 3°C, respectively, when placed in an ice slurry at 1°C. Lambooij et al. (2002a) found that 5% of European eels (*Anguilla anguilla*) were not successfully stunned when transferred from 18ºC water to iced water at an average temperature of 0.2ºC, however all eels were killed within an average of 27 seconds when they were transferred to cold brine at -18ºC. Fish stunned and killed in ice slurry nevertheless tend to have improved product quality indices including reduced buildup of lactic acid, plasma cortisol and glucose, increased muscle pH and delayed onset of rigor mortis compared to fish killed by asphyxia or some other methods such as exposure to CO_2 (Acerete et al. 2009). Indeed, many of the physiochemical product quality indices of fish killed in ice slurry can equal those obtained using so called “faster” and “more humane” killing methods such as percussive stunning, electrocution or brain spiking (Poli et al. 2005, Scherer et al. 2006, Giuffrida et al. 2007), indicating that the process of inducing hypothermia via an ice slurry is not necessarily overtly stressful or causes additional stress above that of handling alone (Poli et al. 2005).

Thus even though large bodied and/or cold adapted finfish may take a relatively long time to die in an ice slurry, for smaller finfish less than approximately 500 grams, thermal shock due to the rapid initial decline in body (particularly brain) temperature when the water temperature differential is above 20°C (Stevens and Fry 1970) greatly shortens the time to loss of brain function and death (Wilson et al. 2009, Blessing et al. 2010). However, cooling rates of fishes can vary due to physiological and anatomical differences between fish species (Skjervold et al. 2002), hence the stunning effect from initial rapid cooling is not likely to be universal and this technique may be most effective only for smaller tropical or warm temperate fish species acclimated to higher water temperatures (Blessing et al. 2010). Nevertheless, based on their findings for bony bream, Blessing et al. (2010) stated that ice-slurry immersion should be considered as an acceptably humane method of killing some fishes for research, subject to appropriate trials on other warm-water species.

Despite evidence to the contrary, hypothermia using an ice slurry was not considered a humane method of killing fish by ANZCCART, but these guidelines are dated and are under review (Reilly 2001). The use of hypothermia for killing fish was also not endorsed by the AVMA (2007), EFSA or FAWC (FAWC 1996, EFSA 2004). However, based on results of Wilson et al. (2009), ice slurry has recently been recommended for euthanasia of tropical zebra fish in US research institutions[3], while the NSW Department of Primary Industries (2012) considered that small to medium-bodied, warm-water fish species may be dispatched humanely using an ice slurry. The conditions for the slurry prescribed by NSW Department of Primary Industries (2012) were that it should contain at least equal volumes (>1:1) of crushed ice and water, that the water temperature should be closely monitored, and more ice added as required to maintain its temperature at 0^{o}C or less during addition of fish.

3.3 Exsanguination (bleeding out)

Exsanguination, or bleeding out, is a process that is often required during the slaughter of finfish in order to maximize the eating quality of the final product (Southgate and Wall 2001, Robb and Kestin 2002). Exsanguination is usually administered after some from of stunning (Southgate and Wall 2001), however exsanguination without stunning is also used (Robb and Kestin 2002). To achieve exsanguination, the gills or isthmus are cut, or one or more gills are manually pulled out, or the caudal vein is cut, after which the fish is usually returned to water to bleed (Robb and Kestin 2002). Exsanguination alone is a relatively slow method for killing fish: Atlantic salmon (*Salmo salar*) killed by exsanguination took 4.5 min to lose brain function after gill-cutting without prior stunning (Robb et al. 2000), while Erikson et al. (1999) reported that 10 to 15 minutes was required to ensure death after bleeding by a gill cut in the same species at a lower water temperature. Other fish species may take even longer to die from exanguination. For example, Morzel et al. (2002) found that bleeding by cutting the gill arches and returning turbot (*Psetta maxima*) to the water was a very slow killing method for this species: as many as five out of 8 fish showed a response to external stimuli (tail pinching) after 30 minutes at 16°C. Morzel et al. (2002) also found that cutting the caudal vein and placing turbot back in water at an ambient temperature of 16°C was an even less efficient method, since no fish was killed

[3] http://oacu.od.nih.gov/ARAC/documents/Zebrafish.pdf

or even stunned in 90 minutes, presumably because the wound healed, resulting in unsuccessful exsanguination (Morzel et al. 2002).

Out of the four bleeding procedures tested by Morzel et al. (2002), the most rapid killing method was cutting four gill arches and placing the fish immediately in an ice slurry. However, even with this method the turbot exhibited adverse reactions such as vigorous escape attempts and wide opening of the mouth and gills, as well as responses to tail pinching in 1 out of 8 fish after 15 minutes (Morzel et al. 2002). Bleeding-out is most likely to be effective when applied to active fishes which require high concentrations of oxygen (e.g. Scombridae and Salmonidae) (Davie and Kopf 2006). Less active fishes, such as catfish (Ictaluridae), may survive long periods of poor blood flow to the brain, and for these species other killing methods (brain spiking and percussive stunning) have been recommended (Davie and Kopf 2006). Since there are no reports that exsanguination without stunning achieves a better bleed-out than exsanguination after stunning, bleeding fish after stunning is likely to improve welfare without compromising quality (Robb and Kestin 2002, Davie and Kopf 2006). Indeed, the NSW Department of Primary Industries (2012) stated that finfish should only be bled after the fish has been stunned or dispatched using another method such as brain spiking or percussive stunning.

3.4 Decapitation / Cervical dislocation

Decapitation and/or cervical dislocation are killing methods that sever the head from the body or break the cervical bones of the neck. Spinal section of the cervical vertebrae with a sharp instrument such as a knife or cleaver is another derivation of this technique. For some species of fish, death occurs immediately after cervical dislocation resulting in minimal stress (for example, in whiting *Sillago* spp., BK Diggles, personal observations), however for other fish species death may not be immediate after decapitation or cervical dislocation unless both the brain and spinal cord are subsequently pithed. For example, decapitation has been used to kill eels, which are notoriously hard to kill (Robb and Kestin 2002). However, even with the head severed from the body, Verheijen and Flight (1997) reported it took up to 13 minutes before eels ceased reacting to noxious stimuli, and up to 27 min elapsed before total loss of brain function occurred (Robb and Kestin 2002). The AVMA (2007) recommended that fishes, as well as amphibians and reptiles, can be euthanased by decapitation, but only after being stunned first by cranial concussion (= percussive stunning). Davie and Kopf (2006) considered that decapitation was similar to brain spiking in terms of injury, distress, and difficulty in restraining conscious fish, and recommended its use only on unconscious fish, after rendering the fish unconscious via methods such as percussive stunning. Similarly, cervical dislocation, decapitation and spinal section were considered acceptable methods of euthanasia of fishes by the ANZCCART, but only if the procedures were performed on fish that were previously stunned or anaesthetised (Reilly 2001).

3.5 Shooting

Shooting of finfish can be done by recreational fishers using guns, spearguns or bow and arrow. Shooting with rifles or handguns is sometimes performed in some aquaculture industries where large tuna are caught with a gaff or by a diver, pulled to the surface and shot in the head with a twelve bore shotgun, rifle or handgun (Robb and Kestin 2002). Shooting with a gun can result in immediate death if the shot is accurate, resulting in minimal stress, and for this reason the method was developed to kill high value fish quickly to prevent damage and stress during escape attempts (Robb and Kestin 2002). Shooting of finfish with rifles or handguns is not generally done by recreational fishers in Australia, due to safety reasons as well as strict gun control laws that mean only a very small number of fishers now have access to these weapons. However, in remote locations some charter operators may possess a gun for occupational health and safety to quickly subdue large dangerous fish or sharks, and/or for self defence against attack from crocodiles, or even pirates (B. Diggles, personal observations).

Spearfishing was performed by traditional fishers worldwide for millennia, originally by throwing sharpened sticks or sticks with bound spearheads made from shell, stone, bone or the barbs of stingrays (Davidson 1934, Barton et al. 2009). Today, recreational spearfishers use modern equipment consisting of spearguns powered by elastic or compressed air. Spearfishing has one clear welfare benefit over virtually all other forms of fishing, that being there is virtually no bycatch as spearfishers select the animal they wish to take prior to shooting it (Diggles et al. 2011a). Death of the fish can be instantaneous if a "kill shot" is performed (i.e. one that kills the fish immediately by penetrating vital organs or the brain), however issues related to the welfare of fishes that are speared but escape from the spear remain, as do those related to humane killing of speared fish that are not taken with a "kill shot" (Diggles et al. 2011a). For the latter, the options for killing available to other recreational fishers (including exanguination, percussive stunning, decapitation and iki-jime) are available to spearfishers, although asphyxiation and hypothermia are not available options if the spearfisher remains in the water.

Fishing with bow and arrow was also a traditional fishing method used for millennia (Barton et al. 2009). In Australia a minority of recreational fishers today continue to target some fish species (particularly invasive species such as European carp, *Cyprinus carpio*) using a bow and arrow. The situation regarding welfare outcomes for finfish shot using bow and arrow are virtually identical to those relating to use of spearguns, except that all options for killing available to other recreational fishers (asphyxiation, exanguination, hypothermia, percussive stunning, decapitation and iki-jime) are also available to bow and arrow fishers.

3.6 Percussive stunning

Percussive stunning is a process whereby fish are killed by removing them from the water, restraining them and a blow or blows are delivered to the head using a club ("priest") or similar (Robb and Kestin 2002, Poli et al. 2005). When the blow is correctly applied and is of adequate force, all movement and brain function is lost immediately (Kestin et a1. 1995, Marx et al. 1997, Robb et al. 2000, Morzel et al. 2002, Lambooij et al. 2002b), but if applied incorrectly, or with insufficient force, insensibility may not be immediate (Kestin et al. 1995, Robb et al. 2000), or the fish may recover consciousness (Davie and Kopf 2006), which is why some authors recommend that percussive stunning should always be followed by pithing, bleeding-out or decapitation (Davie and Kopf 2006).

Fish killed by percussive blows show reduced physical activity at slaughter, reduced post mortem muscle acidification due to lactic acid buildup, and slower onset of rigor, all of which are associated with minimal stress and improved flesh quality (Azam et al. 1989, Marx et al. 1997, Poli et al. 2005, Duran et al. 2008, Digre et al. 2011). Indeed, this method is considered amongst the fastest and most humane methods of dispatch of finfish available to recreational fishers in the field (Davie and Kopf 2006). Furthermore, because less accuracy is required to induce unconsciousness due to brain injury when using a blunt club than when using a narrow spike, percussive stunning requires little skill and as a result is the killing method primarily recommended for recreationally caught fish, even if other procedures such as brain spiking or exanguination are to be used (Davie and Kopf 2006).

Applied correctly, percussive stunning can quickly kill virtually all species of fish. For example, flatfish such as turbot (*Psetta maxima*) can be difficult to kill using methods such as ice slurry, asphyxiation, exanguination or electrocution (Morzel et al. 2002), and percussive stunning was the only method tested that killed the fish immediately (Morzel et al. 2002). However, some authors consider that percussion is not suitable for killing certain species, such as eels (van de Vis et al. 2001). The AVMA (2007) considered that most fishes, amphibians and reptiles can be euthanased by percussive stunning followed by decapitation, pithing, or some other physical method. Similarly, percussive stunning was considered an acceptable form of euthanasia for fishes by the ANZCCART and the AVMA, provided it was immediately followed by brain destruction (Reilly 2001, AVMA 2007). The NSW Department of Primary Industries (2012) considered that percussive stunning was the preferred method of dispatch for finfish caught by recreational fishers, provided it is done swiftly and delivered to the correct area. They recommended a sharp blow to the head should be inflicted in the area just above the eyes using a special tool such as a heavy wooden handle or a priest, prior to any other treatments such as bleeding/exanguination (NSW Department of Primary Industries 2012).

3.7 Brain Spiking / Iki-jime

Together with percussive stunning, brain spiking (also known as pithing or iki-jime – that latter being a Japanese term denoting 'live killing, or to terminate while alive') is the most rapid method of dispatch of fish available to recreational fishers in the field (Davie and Kopf 2006). Administered accurately, brain spiking can be a one-step process which results in the lowest levels of stress and maximal product quality in slaughtered finfish compared to all other methods of dispatch (Boyd et al. 1984, Poli et al. 2005, Davie and Kopf 2006). Once the brain is destroyed, the fish is immediately killed (Lambooij et al. 2002b), which drastically reduces stress, lactic acidosis, bruising and other undesirable changes which 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 minimizing pH drop due to lactic acid buildup, and also significantly delays the onset of rigor mortis, especially if the iki-jimed fish is placed immediately on ice (Boyd et al. 1984, Harada 1988, Lowe et al. 1993).

However, the brains of fish are not large and a high level of skill and a certain amount of anatomical knowledge is needed to accurately pith the brain of a live fish (Lambooij et al. 2002b, Poli et al. 2005). Further, effective restrainment of the fish is an important prerequisite needed for accurate brain spiking (Lambooij et al. 2002b), hence the difficulty of this process may be amplified in some recreational fishing scenarios, such as at sea on small boats (Davie and Kopf 2005). Because of these reasons, it is possible to miss the small target point and the fish may suffer during the procedure (Poli et al. 2005). Because of this, percussive stunning is often recommended prior to use of the iki-jime method, as this ensures the stunned fish are easier to restrain during the spiking process (Davie and Kopf 2006). Indeed, ANZCCART and the AVMA considered that brain destruction by pithing was an acceptable form of euthanasia for fishes, provided they were firstly stunned by percussion or some other means (Reilly 2001, AVMA 2007). In contrast, the Western Australian Department of Fisheries (2012) simply recommends that "live fin fish should be spiked in the head (iki-jime) with a narrow spike, or blade, to penetrate and destroy the brain", prior to further preparation for the table.

3.8 Results from website survey

A three question survey was conducted via the Fishing World magazine website over 100 days between February and May 2012[4]. The survey questions were 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 to do so. A question exploring the use of live bait was also included to obtain information on this topic. The survey was advertised via the Fishing World website, in Fishing World Magazine, and through electronic mailouts sent from the Fishing World website that are sent to around 12,500 e-mail accounts every week. Subscription to the e-mail service is free, as is access to the Fishing World website, hence cost was not an obstacle likely to discourage access to and participation in the survey. 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. Survey data by Roy Morgan Research on newspaper and magazine readership in Australia as of May 2012 found that Fishing World magazine has a readership of 1.0 -1.1% of Australias population over 14 years of age (194,000 – 208,000 people). The audience for this magazine is regarded as comprising a sub-section of more avid fishers, hence the results of the survey may not necessarily be completely representative of responses that may be expected from "average" or occasional recreational fishers. After the 100 day period, the survey was completed by respondents from 450 IP addresses.

Of the 446 respondents to question 1, only 36 (8%) stated that they released every fish they caught, indicating that 92% of respondents dispatched at least some fish during the course of their fishing trips (Figure 1). The second question examined use of live bait. Respondents were given 4 options and asked to select one option that best reflected their individual circumstance. The responses indicated that 55% of the respondents surveyed had used live bait at some time (Figure 2). Only 3% of respondents exclusively used dead bait, while 13% of respondents used artificial lures exclusively (Figure 2). A total of 29% of respondents only used dead bait or lures during their fishing activities (Figure 2). Survey question 3 attempted to determine the methods used by recreational fishers to kill their fish. Respondents were asked to select one of the 7 options provided to best describe how they killed the fish they caught. The majority of respondents (79%) used best practice methods for killing their catch. These included option 4 (percussive stunning or decapitation, 9%), option 5 (iki-jime, 9%), option 2 (ice slurry, 9%), or option 6 (a combination of either bleeding, stunning/decapitation or iki-jime followed by ice slurry, 52%). Only 13% of respondents indicated they killed their fish by exanguination alone (option 3), while only 5% indicated that they killed their fish by asphyxiation (option 1). Option 7 (not applicable) was included for fishers who released all of their catch, and this was selected by 4% of respondents.

[4] http://www.fishingworld.com.au/news/humane-dispatch-survey

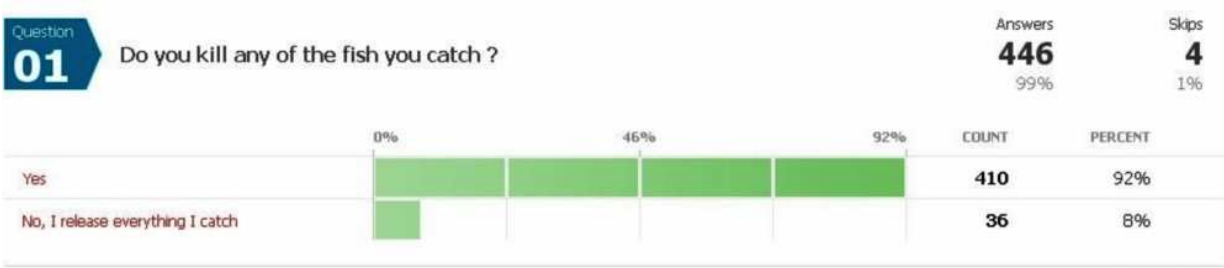

Figure 1. Survey question 1 examined whether recreational fishers killed any of the fish they caught. The respondents indicated that 92% of fishers killed at least some of the fish they caught, while 8% released every fish they catch.

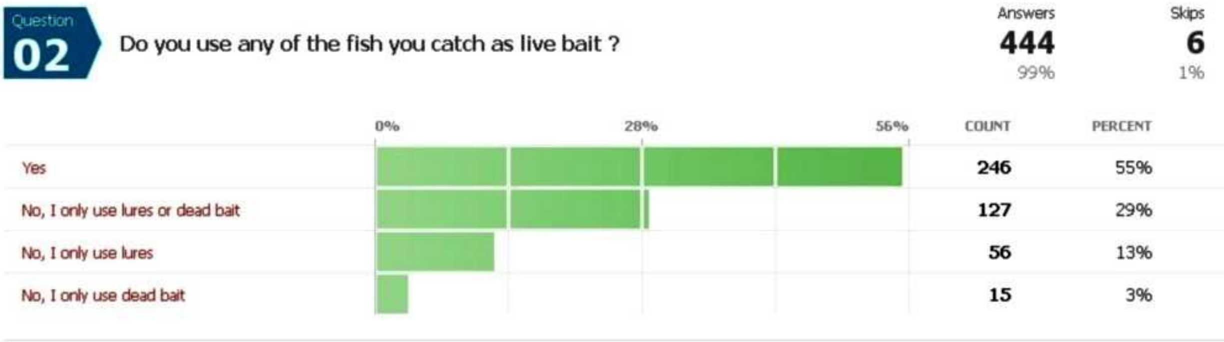

Figure 2. Survey question 2 examined use of live bait. 55% of the respondents surveyed had used live bait at some time, while 13% of the respondents used artificial lures exclusively.

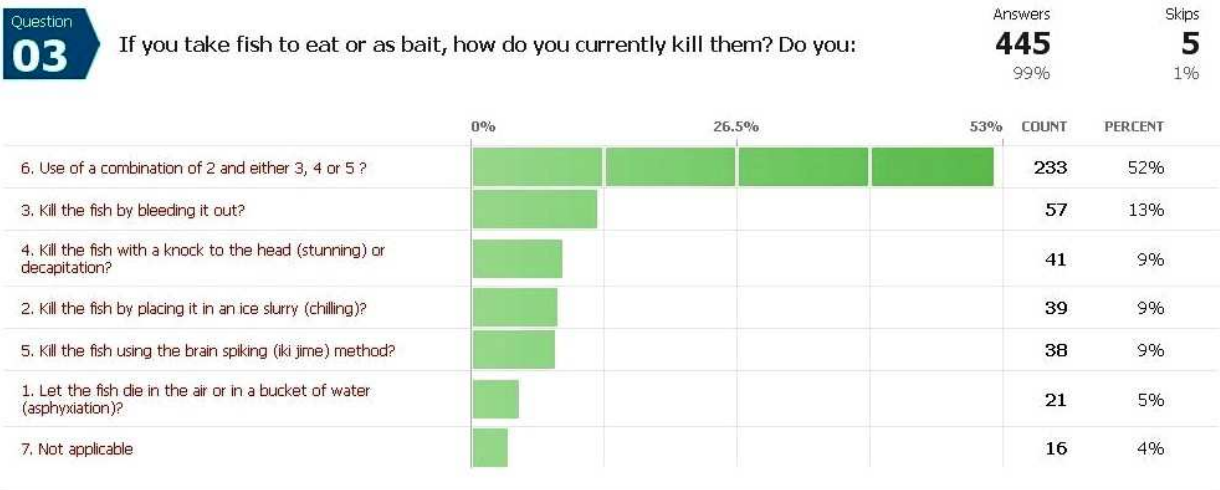

Figure 3. Survey question 3 examined how respondents killed their fish. The majority of fishers (79%) used best practice including percussive stunning, (9%), iki jime (9%), ice slurry (9%) or a combination of bleeding, stunning or iki jime followed by ice slurry (52%). Only 13% of respondents indicated they killed their fish by exanguination alone, and only 5% killed their fish by asphyxiation.

4.0 Discussion

As originally discussed by Robb and Kestin (2002), a review of the subject shows that fish killing methods are incredibly diverse, but fall into two broad categories: those that induce loss of sensibility slowly, and those that achieve this rapidly (Robb and Kestin 2002). The universal principles of humane slaughter require a first step of rapid loss of consciousness without avoidable stress, followed by death as assessed by loss of brain function without regaining consciousness (Southgate and Wall 2001, Davie and Kopf 2006). In general, this and other previous reviews on the subject pertaining to finfish have demonstrated that those methods that induce loss of sensibility over a long period of time (asphyxiation, exanguination) are stressful and tend to impinge more on the welfare of the animal and are detrimental to the overall quality of the carcass (Robb and Kestin 2002, Poli et al. 2005, Gregory 2008). In contrast, methods that cause a rapid loss of sensibility (shooting, cerebral percussion, brain spiking) result in minimal stress and the highest quality product, providing that they are carried out correctly (Robb and Kestin 2002, Poli et al. 2005, Gregory 2008) (Table 1). Nevertheless, the situation regarding what methods are considered "humane", and what are not, is by no means black and white. Indeed, this review highlighted grey areas in relation to the acceptablility and "humaneness" of a couple of methods commonly employed for killing fish caught by recreational fishers in Australia, namely decapitation/cervical dislocation, and hypothermia in an ice slurry (Table 1).

Table 1. Summary of humane acceptability (or otherwise) of the various methods of killing fish examined in this literature review.

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 conscious fish
Shooting	Hypothermia in ice slurry [O]	Asphyxiation
Percussive stunning[+]	Decapitation/cervical dislocation*	Exsanguination /bleeding out*
Brain spiking/iki-jime*		

[+] Should be followed by iki-jime, bleeding or decapitation/cervical dislocation to prevent recovery.
* Ideally used on fish rendered unconscious by percussive stunning.
[O] For best quality and welfare, large fish (>500 grams) should be stunned and/or iki-jimed prior to placement in ice slurry.

The vast majority of the research into humane killing of finfish has been conducted in Europe, where interest in the subject has been driven mainly by a need to define humane killing methods in the face of rapid increases in aquaculture production (FAWC 1996, EFSA 2004, Hastein et al. 2005, Ashley 2007, Lines and Spence 2012). However, because of the Eurocentric focus of this research, some methods of killing fish (namely hypothermia in an ice slurry and decapitation/cervical dislocation), have been considered to have failed to meet certain criteria for humaneness, based on data from European fish species alone. In contrast, there is evidence to suggest that at least some species of warmwater fish (Poli et al. 2005, Wilson et al. 2009), including Australian native species, may respond differently, as shown by Blessing et al. (2010) for bony bream, and by informal observations of the responses of other species such as whiting (*Sillago* spp.) to treatments such as ice slurries and cervical dislocation (BK Diggles, personal observations). These data demonstrate that it is not best practice to blindly accept results from fish welfare studies done in temperate Europe on European species and attempt to apply them to very different species of finfish that are adapted to survive in vastly different environments, such as in tropical Australia. The results of the website survey conducted here, as well as the authors personal observations, show that both hypothermia in an ice slurry and decapitation/cervical dislocation are widely used methods for killing a variety of fish species in Australia. The available science suggests at this time that it would be premature and unwise to disregard these methods without further study. Hence in the context of recreational fishing (and for that matter, commercial fishing, aquaculture and laboratory work as well), we concur with Blessing et al. (2010) in stating that methods such as ice-slurry immersion and decapitation/cervical dislocation should remain accepted as humane methods of killing fishes under Australian conditions, at least until appropriate scientific studies on Australian native species prove otherwise.

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. 2011a). While asphyxiation remains commonly used by many fishers around the world, the website survey conducted during this study indicated that only a minority of Australian recreational fishers (c. 5%) continue to utilise this method. Furthermore, the survey found only a relatively small number of fishers (13%) used exanguination alone as a method of dispatching their fish. This positive result may be in response to increased education in recent years in both Australia (Recfish Australia 2008) and overseas (Cooke and Sneddon 2007, EIFAC 2009) that may have encouraged recreational fishers to use more humane slaughter methods such as ice slurrys (with or without exsanguination), cerebral percussion and iki-jime. The use of these methods alone, or in combination, is not only generally considered to be "best practice" and "more humane" (Davie and Kopf 2006), they have the added benefit of improvement in product quality (Poli et al. 2005).

This literature review has confirmed that recreational fishers in Australia are well placed to employ best practice methods of humane killing of the fish they harvest, while the survey suggests that uptake of these methods may be widespread, provided recreational fishers are informed and have access to appropriate educational materials on the subject. This review finds that the recommendations of the 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 iki-jime, followed by hypothermia in an ice slurry (which is usually performed in conjunction with exsanguination), which will maximise both fish welfare and product quality.

Regardless of whether the fish has been previously stunned or not, the iki-jime method of brain spiking (if administered accurately), can be a one-step process which results in the lowest levels of stress and maximal product quality in slaughtered finfish compared to all other methods of dispatch (Boyd et al. 1984, Harada 1988, Poli et al. 2005, Davie and Kopf 2006). Indeed, dedicated brain spiking tools are now widely available in fishing tackle shops, while recreational fishers can also employ other implements such as sharpened screwdrivers with similar effectiveness, hence a lack of availability of suitable equipment is not a barrier to uptake of the method. Furthermore, the iki-jime method is the only best practice method of humane killing available to spearfishers while they are underwater if they fail to kill their quarry immediately by shooting with a head shot. However, despite all of these benefits for the iki-jime technique, the effectiveness of the technique as a humane method of dispatch is reliant on the ability of the fisher to firstly accurately locate the brain and then determine the best method of penetrating the cranial cavity with a suitable implement in order to destroy the brain quickly and effectively. Average recreational fishers with limited anatomical knowledge of the fish they are catching are likely to find the process difficult, and informal interviews with a variety of fishers (BK Diggles, personal observations) found evidence that fear of missing a relatively small target with the spiking implement may be preventing many recreational fishers from attempting the brain spiking procedure. This is why the current project was undertaken, in order to provide accurate information on the iki-jime procedure to better equip recreational fishers with the "how to" information needed to encourage wider use of brain spiking as a method of humane dispatch.

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