Reducing the By-catch of Platypuses (*Ornithorhynchus anatinus*) in Commercial and Recreational Fishing Gear in New South Wales

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The problem of platypus by-catch mortality in the eel, yabby and carp trap fisheries in New South Wales is reviewed, and the results of several experiments to determine the effectiveness of gear modifications to reduce platypus by-catch are presented. Entrance screens with 50-60 mm openings prevented the entry of platypuses into eel or yabby traps. Larger screens were not effective as a deterrent to platypuses entering traps. By-catch of platypuses in the eel fishery can be minimised by restricting traps to estuarine areas, where platypuses seldom occur, and by providing air spaces in the cod ends of traps used in impoundments and farm dams. Prohibiting the use of yabby traps in areas where platypuses are known to occur provides the most practical protection against by-catch of platypuses in this fishery. Platypuses were unable to exit from prototype carp traps, designed to permit escape of air-breathing species, but the provision of appropriately-sized openings at the base of the entrance funnels in these drum traps permitted platypuses to escape.

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INTRODUCTION

By-catch mortality of air-breathing vertebrates, including several species of freshwater turtles and diving birds, water rats (*Hydromys chrysogaster*) and platypuses (*Ornithorhynchus anatinus*), has been recognised for some time as a significant problem in various inland fisheries in Australia (Jackson 1979; Beumer et al. 1981; Grant 1991, 1993; Grant and Denny 1991; Leadbitter 2001). Such by-catch mortality of platypuses is of particular concern in small streams, where multiple drownings of breeding individuals have the potential to impact severely on small local populations. For example, an abandoned fyke net in a tributary of the Gellibrand River in Victoria was found to contain the skeletons of 17 platypuses (Serena 2003).

There has often been conflict between the desires of fishers to maximise catches of their target species, and the implementation of effective methods to reduce non-target by-catch. This has resulted in a diverse range of regulations enacted by fishery authorities and voluntary gear modifications by fishers aimed at reducing the mortality of non-target species (e.g. Leadbitter 2001). Unfortunately, little research or monitoring has been done to assess the effectiveness of voluntary and regulated gear modifications.

An historical assessment of inland fishing in New South Wales showed that commercial fishing probably resulted in significant platypus mortality when small-mesh nets were used (Grant 1991, 1993; Grant and Denny 1991). No commercial or recreational fishery using nets or traps to capture native fish species or salmonids in freshwater sections of coastal rivers is now permitted in New South Wales (NSW), but there is a commercial eel fishery based on the use of baited traps in estuaries, farm dams and a few large impoundments. West of the Great Dividing Range, the commercial fishery for native fin-fish species was phased out in 2001. Fishers previously involved in that industry have been encouraged to fish for yabbies, mainly (*Cherax destructor*), using “Opera house” traps (Rankin 2000). The introduced carp (*Cyprinus carpio*) is also targeted by commercial fishers using a variety of gear, including traps, mesh and haul nets and electrofishing.

There are a number of options to prevent or minimise mortality of air-breathing wildlife species in traps. The most direct way is to ban fishing in areas where these potentially vulnerable species occur.

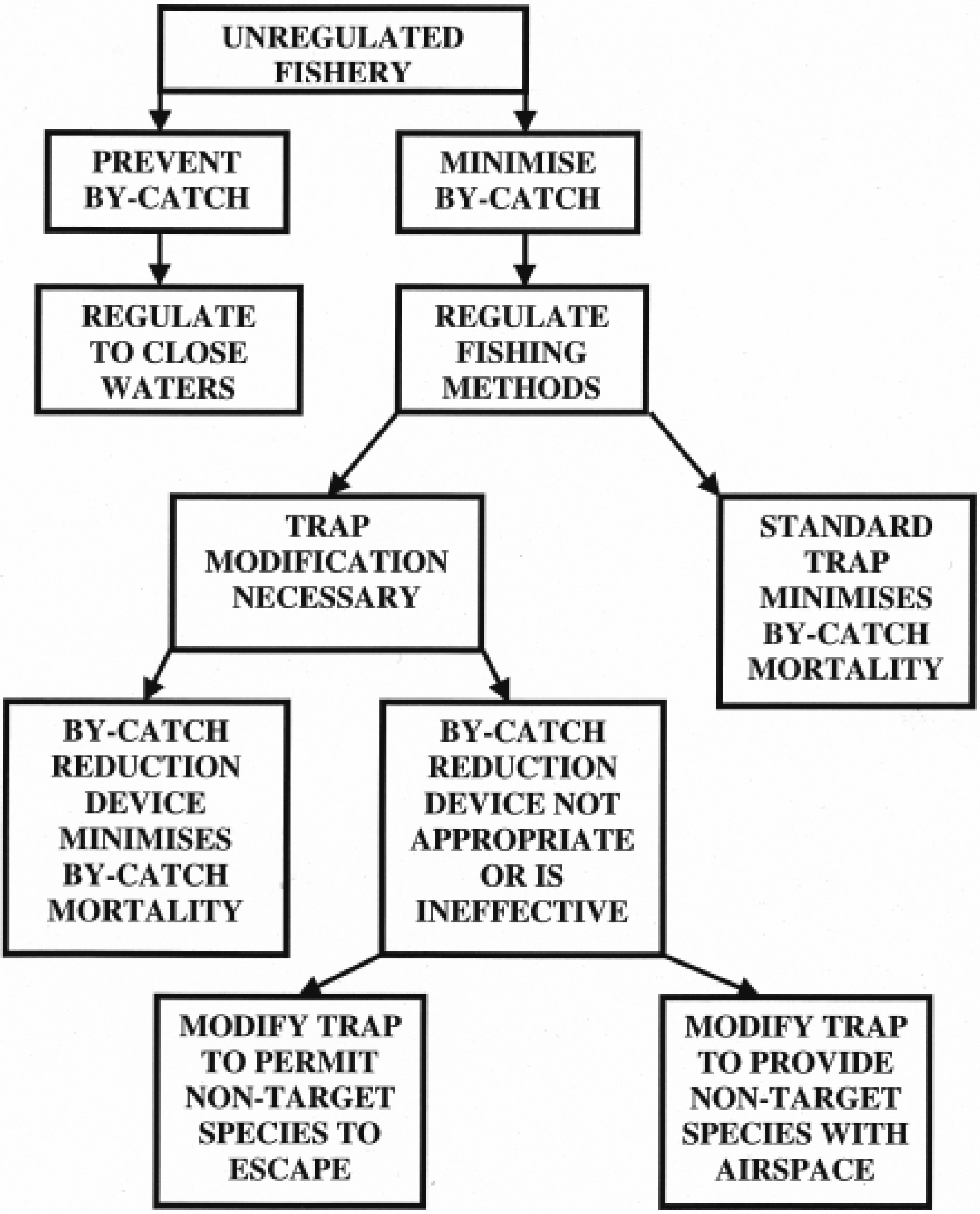


Figure 1. Schematic diagram of possible options available to achieve by-catch reduction of air-breathing species in fisheries operations.

However, maintaining a commercial fishery, while still addressing the issue of by-catch mortality, is to adopt capture methods which minimise by-catch. Mortality of air-breathing non-target species can be reduced or prevented by trap modifications, such as fitting devices to keep non-target species out (By-catch Reduction Device - BRD), providing a route to let them escape or permitting access to an airspace once they have entered a trap. Figure 1 summarises these possible options, which need to be explored in relation to the following issues:

Fishery requirements. The practicalities and economics of the fishery, in terms of trap design and cost, catch per unit effort, size of target species, and even the necessity to hide traps from possible interference and/or vandalism must be considered. For instance, a device which reduces by-catch but unduly restricts the entry of the target species into a trap may be economically unviable.

Behaviour of target species. It is necessary to know the reactions of the target species to trap modifications provided for non-target species. For example, the target species may escape via holes provided for the non-target species, or its behaviour could prevent the non-target species from utilising air spaces or escape routes provided.

Behaviour of non-target species. In fishing areas where a number of potential by-catch species occur, escape holes, BRDs or air spaces in traps may not be suitable for all potential non-target species. For example one species may use an escape hole in a trap which will not be used by another species.

This paper reviews past efforts to reduce the mortality of platypuses in the eel, yabby and carp fisheries and reports on a number of recent studies carried out to assess the effectiveness of trap modifications designed to reduce by-catch mortality of this species in these fisheries. The three fisheries are reviewed in separate sections of the paper and the experiments pertinent to each are discussed within these sections.

THE EEL FISHERY IN NEW SOUTH WALES

Freshwater eels were initially captured in upper estuarine waters of NSW as a by-catch of other fisheries. A fledgling industry targeting eels, based on the use of traps, was established in the early 1980s. At that time prices for eels were low but in the late 1980s and early 1990s a high-value export market to Asia was established. This increased interest in the fishery and the adoption of potentially more productive fishing methods. Requests were made by fishers to extend their operations into freshwaters using fyke nets (Figure 2a), which were known to be involved in the mortality of air-breathing wildlife species in the eel fisheries both in Tasmania and in Victoria (Jackson 1979; Beumer et al. 1981; Grant 1991). The potential fishers drew attention to a brief experiment in Lake Crescent and Dee Lagoon in Tasmania, where two fyke nets screened with 100 mm square mesh grids, and two unscreened control nets, were deployed in those lakes for six days. During that time, two platypuses were captured in the unscreened nets but none were captured in the ones with the screens in place (Grant 1991). While it appeared from this very limited experiment that a 100 mm mesh screen may have been effective in reducing platypus by-catch in Tasmania, an experiment done in the upper Shoalhaven River did not support this contention (Grant, unpublished data). Six platypuses (two female and four male) were placed separately between the river bank and the wing of a fyke net with a 100 mm mesh entrance screen in place. Two of these animals moved off after bumping the mesh and did not enter the fyke net but the other four either passed straight through into the net, or did so after first investigating the screen.

At the time it was also known that elevating the cod end of fyke nets above the surface was effective in permitting platypuses to breathe and survive capture (Jackson 1979; Beumer et al. 1981; Grant 1991; Figure 2b). Unfortunately professional fishers were unprepared to do this, as they feared their catch could be stolen and/or their equipment vandalised if it was visible above the surface.

As a result of the brief experiment with the Shoalhaven River platypuses described above, and advice from experts in the other states regarding the poor compliance of fishers to fit BRDs and/or to raise the cod-ends of their nets above the water level, the request by fishers to use fyke nets for eels, and to extend the fishery to freshwater streams was denied by NSW Fisheries. Instead, the fishery was restricted to estuarine waters, a limited number of impoundments and private farm dams, using baited traps without wings to direct animals into the traps (NSW Fisheries Eel Policy Document, May 1992).

The standard eel traps used in the fishery are shown in Figure 2c. They consist of a metal rod frame 50 cm wide by 40 cm high by 90 cm long covered with 30 mm mesh polyethylene netting. The single entrance funnel (or 'valve') is located in one end of the trap. The opening in the funnel consists of a hole in the netting stretched firmly into a 100 mm wide slot, and pulled approximately 20 cm into the trap. The traps used in estuaries have a 1.5 m long cod end (bag with a draw-string) on the opposite end of the trap from the entrance funnel. Those used in freshwater impoundments and farm dams are similar to the estuary trap, but have a 5 m long cod end. A 150-200 mm diameter float is fastened inside the cod end near the draw-string and from one to three 50 cm diameter aluminium hoops are fastened to the inside of the cod end to keep the passage to the surface open. These traps are normally baited with frozen pilchards or mullet to attract eels.

In the late 1990s anecdotal reports to the National Parks and Wildlife Service, NSW Fisheries and one of the authors (TRG) indicated that platypuses

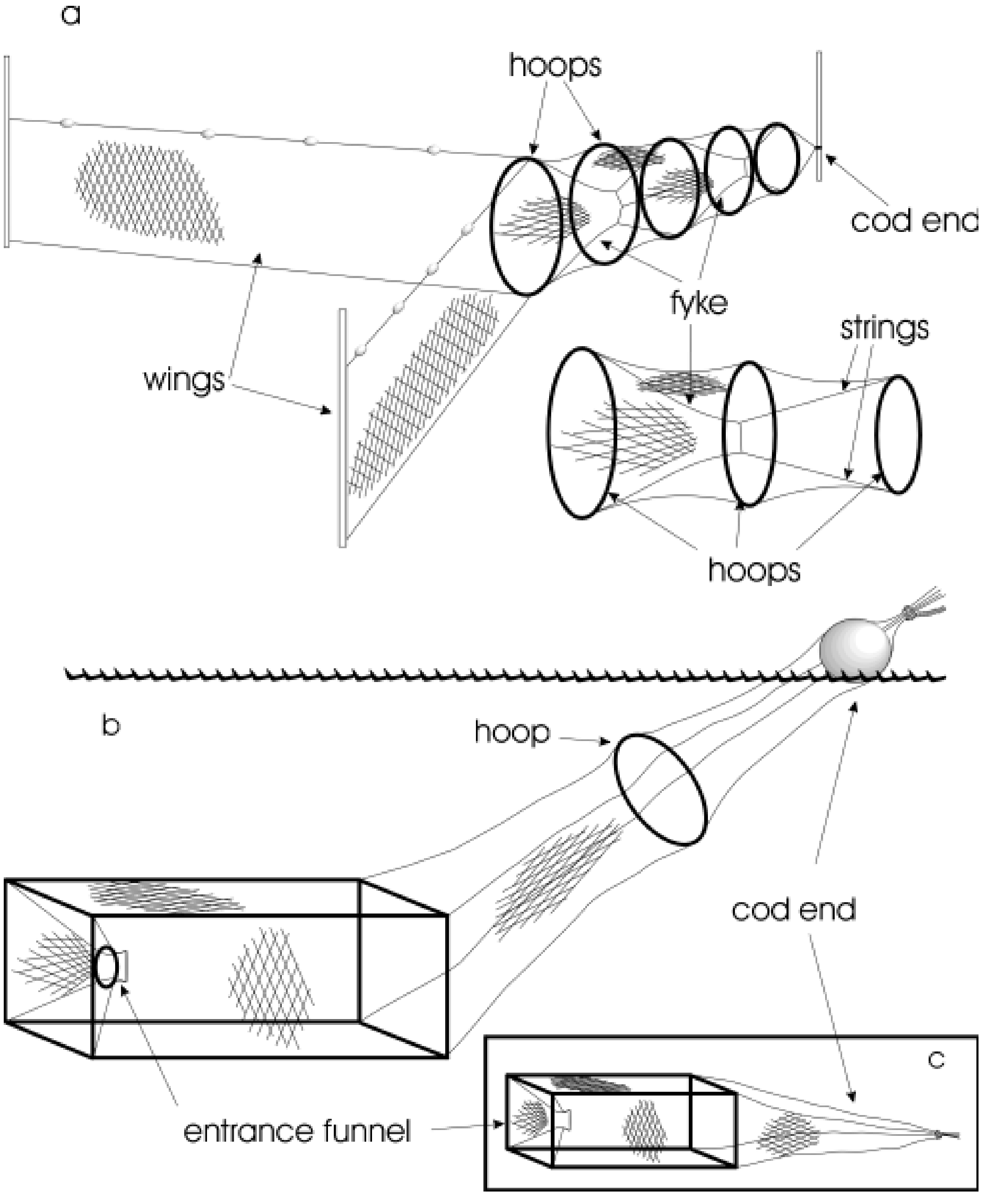


Figure 2. (a) Fyke net used in eel fisheries in Tasmania and Victoria. (b) Commercial eel trap used in the impoundment or farm dam eel fishery, showing the elevated cod-end creating an air space. (c) Typical eel trap used in the tidal estuary fishery in New South Wales. Note the entrance funnel or 'valve' which permits animals to enter the traps in one direction (wide outside to narrow inside). Animals are unable to locate the narrow inside entrance to escape. In Experiment 1 grids were placed at the narrow end of the funnel and in Experiment 2 at the wide end.

were being drowned in eel traps, not only in the upper reaches of some estuaries (where tidal influence changed with river discharges) but also in farm dams and impoundments (where air spaces were not consistently being maintained in the cod ends of traps). As a result, the following experiments were undertaken to determine if it was possible to reduce this mortality of platypuses by trap modification.

EXPERIMENT 1 - Investigation of grid sizes for a platypus exclusion device

The objective of this experiment was to determine the optimum grid size for excluding most platypuses from eel traps. The experiment was conducted in two pools on the Wingecarribee River in New South Wales from 17-19 February 2000.

Methods

The entrance funnels in eight standard eel traps were fitted with grids of different sizes. Each grid was a square divided into four equal openings; the openings in these grids ranged from 55 to 90 mm, in 5 mm increments. The plastic material used to make the grids was reinforced with lengths of 3 mm wire. The traps were fastened end to end (in order of decreasing grid size) and placed on a flat sandy area in the pools where platypuses were to be captured (Figure 3a). Water depth varied between traps but all had an airspace to allow the platypuses to breathe during the experiment.

Trials were done in different pools on two days. Platypuses were captured using unweighted gill nets (Grant and Carrick 1974) during the evening or morning. Once the required numbers of platypuses were captured, each individual was measured and weighed, then tested individually in the experiment. Platypuses were placed through an access door into the first trap leading into an entrance funnel with the 90 mm grid in place (Fig. 3a). Red-filtered lights were used to observe the animals at night, as observations in captivity indicated that platypuses are less responsive to disturbance under red light illumination (Grant, personal observation). The time that animals remained in each trap before passing through each grid was recorded, along with the number of attempts that each animal made to pass through the entrance funnel into the next trap in the series. Animals were removed from the experiment and released immediately if they remained in any trap for more than 15 minutes.

Results

A total of ten platypuses were used in the trials, comprising two adult males (1190 and 1760 g), six adult females (890-1060 g) and two juvenile females (700 and 760 g). Data are summarised in Table 1.

Trial 1: Animals tested at night were reluctant to pass through the 85 mm grid and none passed through the 75 mm grid, while a single female captured in the morning, and tested in daylight readily, passed through all grid sizes, although exhibiting some delay at the 80 and 70 mm grids. However, it was noted that the traps with 85-70 mm grids, which were apparently difficult for the animals to negotiate, were located in slightly shallower water than the rest of the traps. The water level in these traps was located at or just above the top of the grid, whereas the water level in the other traps was well above the top of the entrance grids. It was thought that this difference in water depth may have influenced platypus behaviour. Subsequently, all traps were placed in deeper water (well over the top of the grid) during the second trial.

Trial 2: The largest male (1760 g) could not pass through the 65 mm grid, but the smallest female (700 g) passed through each grid in less than 1 minute. The two slightly larger females did not initially pass through the 55 mm grid. However, it was found that, due to some unevenness on the bottom of the pool, the trap with this grid was in slightly shallower water than the preceding traps in the series. After moving this last trap to a position in slightly deeper water, animals passed through the 55 mm grid almost immediately.

The data from Trial 1 indicated that there was a greater reluctance for platypuses to negotiate the grids when the traps were less submerged. However, Trial 2 confirmed that female platypuses of up to 1 kilogram in weight could pass through a 55 mm grid. Animals smaller than 1 kg passed through easily, while the 1 kg female had a tighter squeeze. Only one male platypus was captured for use in Trial 2. This was the largest animal tested (1760 g) and was stopped by the 65 mm grid. A grid between 55 and 65 mm would apparently be required to exclude most adult male platypuses.

EXPERIMENT 2 - Investigation of possible avoidance of entrance grids by free-swimming platypuses

In Experiment 1, each platypus was closely confined inside the traps so there was an imperative to find an escape route. However, two of the four animals in Trial 2 hesitated, and made more than one attempt to pass through the 70 mm grid, indicating possible deterrent effect of this grid size. Experiment 2 was designed to test whether grids across the outer end of the entrance funnel (Figure 3b) deterred foraging

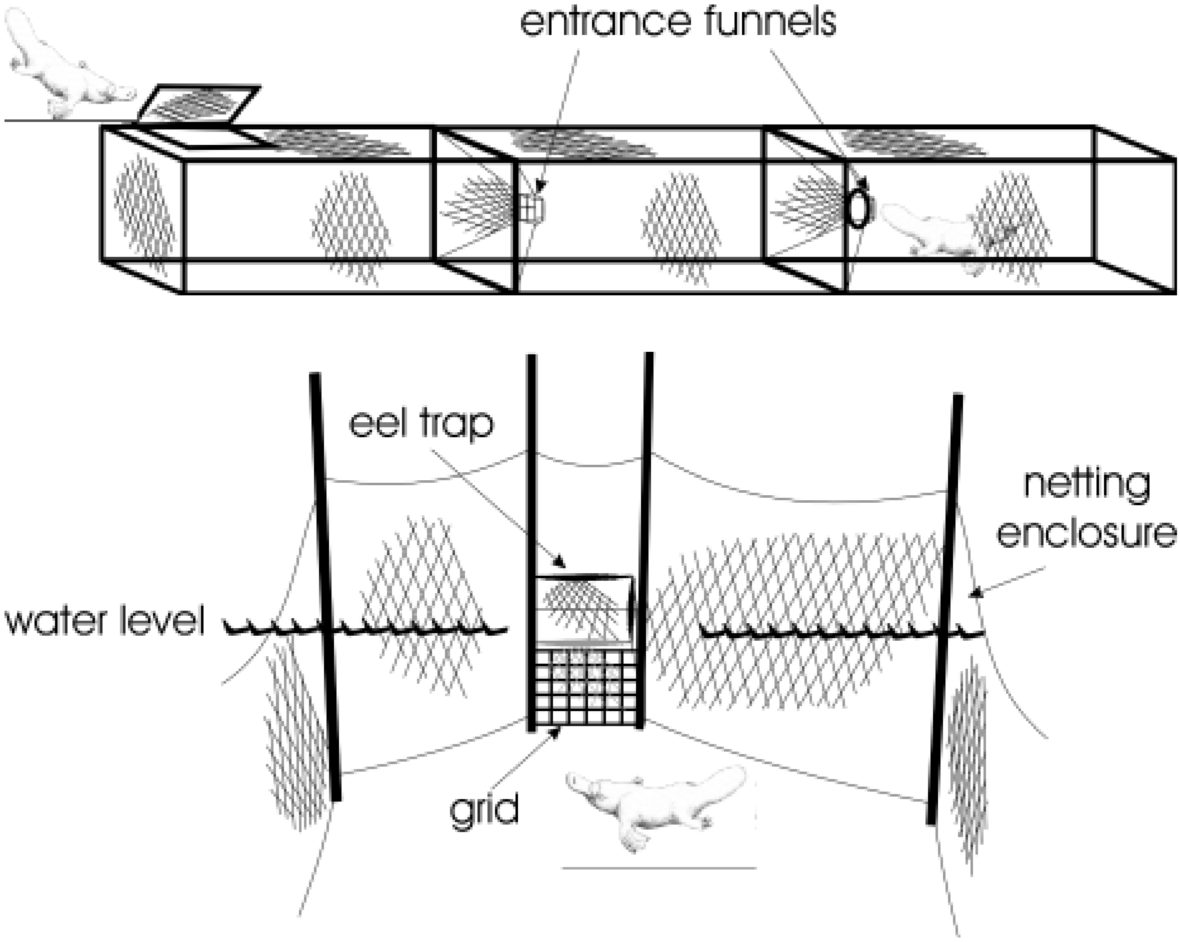


Figure 3. Set up used in Experiments 1 and 2 to test the effectiveness of by-catch reduction devices (BRDs) on entry of platypuses into eel traps. (Top) Experiment 1. Traps were attached together in a line with grids of different sizes at the narrow end of each entrance funnel or 'valve'. (Bottom) Experiment 2. Mesh enclosure in a river pool with trap entrance attached. Note the position of the replaceable rectangular grid across the outer (wide) entrance of the funnel.

platypuses from entering traps. The experiment was done in a pool on the upper Shoalhaven River in the southern tablelands of New South Wales from 17-19 March 2000.

Methods

A circular enclosure, 1.5 m high x 3 m diameter, made from 10 mm mesh monofilament gill net material, was constructed in a pool between the two netting sites where platypuses were captured for the experiment. The enclosure was designed so that the only possible escape for a platypus was through the grid of the entrance funnel of a trap inserted in the enclosure wall. Square grids, made from 4 mm steel rods, with 50, 60, 70 and 80 mm openings were used in this experiment. Each trial was done by attaching a replaceable grid to the entrance funnel of the trap, then placing a platypus into the enclosure (Figure 3b). At night, red-filtered lights were used to observe the animals. The time each animal remained in the enclosure before passing through the grid was recorded, along with the number of attempts that each made to pass through the grid. If an animal did not pass through a particular grid in the test series, this was replaced by the next larger grid in the series and the observations repeated. After the first animal was obviously unable to exit the 50 mm grid, the trials on all others were begun with either the 60 or 70 mm grid.

Results

Eight relatively small platypuses (ranging in

Table 1. Details of platypuses exiting through the various grid sizes within the funnels of eel traps in the two trials of Experiment 1. + = animal exited specific grid size; X = platypus did not exit through specific grid size.

Sex/ age	Weight (g)	90 mm Grid	85 mm Grid	80 mm Grid	75 mm Grid	70 mm Grid	65 mm Grid	60 mm Grid	55 mm Grid
Trial 1									
Male Adult	1190	+	X	X	X	X	X	X	X
Female Adult	1060	+	+	X	X	X	X	X	X
Female Adult	1030	+	X	X	X	X	X	X	X
Female Adult	1020	+	+	+	X	X	X	X	X
Female Adult	920	+	+	+	+	+	+	+	+
Female Adult	890	+	+	+	X	X	X	X	X
Exited		6/6	4/6	3/6	1/6	1/6	1/6	1/6	1/6
Trial 2									
Male Adult	1760	+	+	+	+	+	X	X	X
Female Adult	1000	+	+	+	+	+	+	+	+
Female Juvenile	760	+	+	+	+	+	+	+	X
Female Juvenile	700	+	+	+	+	+	+	+	+
Exited		4/4	4/4	4/4	4/4	4/4	3/4	3/4	2/4

size from 500 to 940 g) were tested in the enclosure at night. Results of the grid-deterrent trials are shown in Table 2.

The first platypus was initially placed in the enclosure with the 50 mm grid. After six attempts to go through the grid it was apparent that the animal would not fit through the spaces. After several tentative attempts at the 60 mm grid it appeared to stop trying to escape through the subsequent grids and remained in the enclosure even after the largest grid was completely removed. The test with the second platypus was started with the 60 mm grid in place, but this platypus was less active than the first animal and made only one tentative attempt to pass through this grid. It then readily passed through the 70 mm grid after only one attempt. Trials with the next three platypuses were all started with the 60 mm grid. All three of these animals swam past the grid at least once before escaping through it. The last three animals were initially trialed with the 70 mm grid, and all passed through it at the first attempt. Overall, two animals out of five appeared to be deterred by a 60 mm grid (40%) and only a single animal was deterred by a 70 mm grid (Table 2).

EXPERIMENT 3 – Platypus behaviour in the elevated cod ends of traps modified for use in farm dams and impoundments

The objective of this experiment was to record the behaviour of platypuses in modified eel traps used in impoundments and farm dams (Figure 2c) and to investigate their ability to negotiate the long cod end extension to the air space. The experiment was done in a pool on the upper Shoalhaven River from 17-19 March 2000.

Method

Two impoundment eel traps, with 5 m cod ends (Figure 2c) were placed in a pool of 0.5 m depth.

Table 2. Details of platypuses deterred from entering the various grid sizes across the entrances of eel traps in Experiment 2. Animals are arranged in the order in which they were used in the experiment. + = animal passed through specific grid size; X = platypus did not pass through specific grid size i.e. deterred; - no data;

Sex/Age	Weight (g)	50 mm Grid	60 mm Grid	70 mm Grid	80 mm Grid
Female Adult	800	X	X	X	X
Female Juvenile	500	-	X	+	-
Male Juvenile	800	-	+	-	-
Male Juvenile	740	-	+	-	-
Male Juvenile	640	-	+	-	-
Female Adult	940	-	-	+	-
Female Adult	900	-	-	+	-
Female Juvenile	690	-	-	+	-

One trap had three evenly spaced hoops in the cod end and the other had only one hoop near the airspace. The cod end of each trap was stretched and tied off above the surface of the water to a star-picket. Three platypuses (one male and two females) were placed consecutively in the trap with three hoops, and one female platypus was placed in the trap with one hoop. Each platypus was observed for 15 to 20 minutes before being released.

Results

In each case the platypus spent several minutes searching the inside of the trap before travelling up the cod end to the airspace. Each took several breaths then travelled to the trap where it again searched around or 'wedged' itself under the entrance funnel. Within five to eight minutes each would again travel up to the airspace for several breaths before returning to the trap. Platypuses travelled back and forth from the trap to the airspace 2-3 times during the 15-20 minutes they were confined in the trap.

DISCUSSION - Eel Trap Experiments

The results of Experiments 1 and 2 indicated that a grid of 50-55 mm would be necessary to exclude platypuses from entry into eel traps. Such a by-catch reduction device (BRD) would almost certainly affect the catch rates and sizes of eels (Koed and Dieperink 1999). This would be unacceptable to commercial fishers, particularly those fishing for adults of the long-finned species (*Anguilla reinhardtii*). Free-ranging platypuses may be deterred from entering traps fitted with external grids of 70 mm or less across the entrance funnels but such screening would be unlikely to significantly reduce platypus by-catch in eel traps.

Raising the cod end to provide an air space would facilitate the survival of platypuses captured in eel traps fitted with elongated cod ends. Platypuses captured in these traps were reluctant to stay at the surface and preferred to remain submerged in the trap between taking breaths. This behaviour, which minimises the time spent at the surface, may be a mechanism to avoid natural predation. Because platypuses must breathe at least every 2-10 minutes (Bethge 2002), captured individuals would need to travel back and forth to the airspace many times during any extended period of confinement after capture. This would be stressful and energetically demanding. It is essential that captured animals be released as soon as possible after capture. Studies using fyke nets (with elevated cod ends) to capture fish have shown that platypuses can survive for periods of up to 24 hours (Grant and NSW Fisheries, unpublished data). However, hypothermia has been reported in platypuses restrained in fyke nets after a few hours in cold conditions (Serena, personal communication). The current regulations in New South Wales demand that eel traps be inspected at least every 24 hours.

The platypus forages aerobically for short periods by holding its breath, following a comparatively large inspiration of air after each dive (Evans et al. 1994; Bethge 2002). The behaviour observed in this study of 'wedging' themselves under an object, and reducing energetic demands by remaining stationary, has been reported in captivity to last up to 11 minutes (Evans et al. 1994; Bethge et al. 2001; Bethge 2002). The function of this behaviour and its occurrence in the wild has not been determined. However, from the perspective of by-catch mortality this behaviour would not prevent platypuses from being drowned in completely submerged traps during normal fishing operations, which demand a period of trap submergence of hours rather than minutes.

Observation of traps with airspaces maintained only by the use of a float has shown that the cod end can easily become twisted or bunched. This situation would undoubtedly prevent a captured air-breathing species from reaching the airspace. This can be avoided by stretching the cod end tightly to a fixed point, either on the bank or a star picket driven into the bottom of the water body. It should be noted however, where traps are set with elevated cod ends attached to a fixed point, allowance needs to be made for anticipated rises in water level as a result of rainfall and/or tidal influences. Attachment of the cod ends of eel traps to a fixed point is mandatory under regulations for the use of eel traps in impoundments and farm dams in NSW.

THE COMMERCIAL AND RECREATIONAL YABBY FISHERY IN NEW SOUTH WALES

The results of the experiments done to evaluate the effectiveness of devices to prevent or deter platypuses from entering eel traps are also directly applicable to both the commercial and recreational 'yabby' [freshwater crayfish] fisheries. Based on the lack of adverse reports and on the assumption that the traps used to capture yabbies were small and did not have mesh wings to direct foraging platypuses into them, Grant (1993) suggested that "yabby fishing poses little threat to platypuses". This conclusion is now thought to be incorrect, as anecdotal reports from a number of states suggest that yabby traps were affecting some local platypus populations. These traps have also been implicated in the mortality of other non-target species, especially freshwater turtles. The drowning of as many as five platypuses in a single yabby trap has been reported, although the species' attraction to these traps is not fully understood. Platypuses are known to locate their prey by sensing the electrical fields generated by muscular activity of the prey species, especially large food items such as yabbies (Pettigrew et al. 1998). A trap containing live yabbies may therefore attract platypuses during their normal foraging activities. Once there is a dead platypus in a trap, more yabbies may feed on the decomposing carcass, which could in turn attract other platypuses into the trap.

Rankin (2000) suggested that a fixed ring 60-70 mm in diameter may prevent platypuses from entering traps and also facilitate their escape. Some commercially available yabby traps are fitted with 90 mm entrance rings, which are effective in excluding larger turtles but which are still reported to have drowned platypuses. The experiments described above for eel traps indicate that a 90 mm diameter ring is too large to exclude platypuses. Similarly, neither the experiments reported here nor anecdotal observations support Rankin's (2000) suggestion that platypuses could escape by returning through a fixed entrance ring.

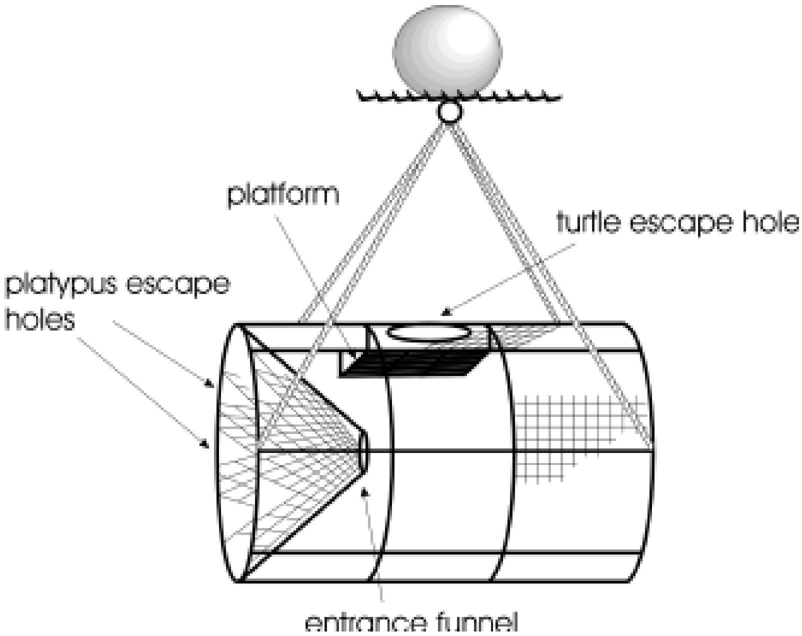
Allanson and Thurstan (1999) evaluated the effect of entrance rings of different diameters in yabby traps using relatively small captive-bred yabbies (*Cherax destructor*). These trials showed that the smallest ring tested (63 mm) still permitted yabbies of the same size to enter the experimental traps as were entering the control traps with no rings fitted. However, the experimental traps caught substantially fewer yabbies. When the results of Allanson and Thurston's (1999) experiments were discussed with commercial fishers, it was concluded that the use of such a small entrance ring was not a viable option for the commercial yabby fishery.

Current regulations in New South Wales exclude the use of traps in commercial and recreational yabby fishing from known platypus waters and 90 mm rings are required in all yabby traps to exclude most turtles. Closed waters are located east of the Newell Highway, from the Victorian border (Murray River) to the Queensland border (Macintyre River), along with local closures around Deniliquin on the Edward River, Echuca on the Murray River and between Narrandera and Darlington Point on the Murrumbidgee River, where platypuses are also know to occur.

THE CARP FISHERY IN NEW SOUTH WALES

Carp (*Cyprinus carpio*) were probably first introduced into Australia around 1850 but did not spread until the introduction of the 'Boolarra' strain in the 1960s. Ecological effects of high densities of carp are poorly understood, but increased bank damage, disturbance of aquatic macrophytes and turbidity are all possible consequences. The overall disruption of riverine food webs by the large biomass of carp is thought to be detrimental to freshwater ecosystems (Schiller and Harris 2001). Carp are harvested in New South Wales using a variety of gear, including traps, haul and mesh nets, and electrofishing equipment. There is considerable overlap between the distribution of carp and platypuses (Boulton and Brock 1999), making the use of submerged traps a concern in this fishery.

A drum trap was constructed by NSW Fisheries (Fig. 4), which was designed to permit the escape of air-breathing vertebrate species, including



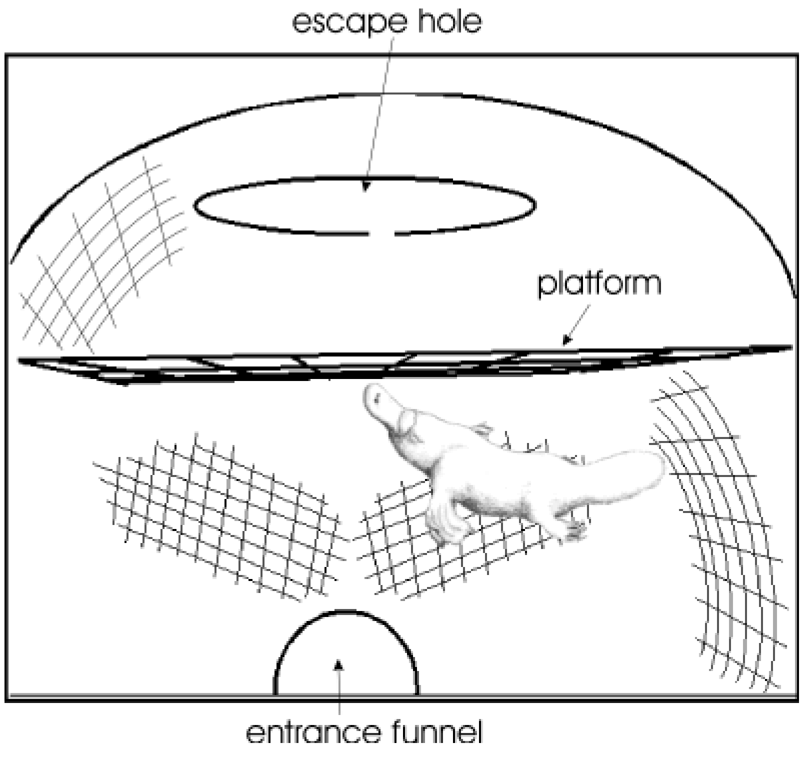


Figure 4. (Top) Modified drum trap showing escape hole in the roof above the mesh platform. Note the entrance funnel (or 'valve') on the left end of the drum. The entrance was sealed in the experiments and the triangular escape holes were made at the base of this funnel. (Bottom) Inside the trap showing the position of the steel mesh platform below the escape opening.

platypuses, water rats, turtles and diving birds, through a hole in the trap's roof. A wire-mesh platform was positioned below the escape hole so that small vertebrate species could pass through the 8 cm gap between it and the roof of the trap and exit through the escape hole, while larger carp would not be able to escape. Carp are also inclined to congregate near the bottom of a trap. The design assumed that air-breathing species would tend to swim towards the surface and search along the roof of the trap for a means of escape (surface/search behaviour). The objective of the following experiment was to test the effectiveness of the escape device for platypuses.

EXPERIMENT 4 - Assessment of escape of platypuses from a prototype carp trap

Platypuses close their eyes, ears and nostrils when under water, using the sensory mechanisms in their bills to find their way around (Pettigrew et al. 1998). It was expected that platypuses in the experiment would exhibit surface/search behaviour and be able to escape from the modified drum trap. The experiment was done in several pools on the Wingecarribee River, New South Wales from 25-27 November 2002 to determine if this expectation was realised.

Method

The trap consisted of a 90 cm diameter x 170 cm long cylinder, covered with black plastic mesh (55 mm x 40 mm), except at the entrance end, where a conical funnel or 'valve' made from 3 mm diameter braided polyethylene trawl netting was strung tightly between the circular steel frame at one end of the trap and an oval ring rigidly suspended inside the trap (Figure 4).

The trap was fully submerged in the pools from which the platypuses were captured. The trap was oriented with the escape hole uppermost. A remote lens for a video camera was

Table 3. Results of Experiment 4. Assessment of escape of platypuses from the carp trap in the Wingecarribee River.

Sex/Age	Weight (g)	Length (cm)	Time in trap (sec)	Approaches to platform	Escape
Female Adult	1080	48.5	150	0	**No**
Male Adult	1880	55.2	165	3	**No**
Male Juvenile	1790	56.5	180	0	**No**
Male Adult	1880	57.5	180	0	**No**
Male Juvenile	1400	53.0	30	0	**Yes**

mounted inside the trap to record the behaviour of the animals and these images were stored for later analysis.

Platypuses were captured using unweighted gill nets (Grant and Carrick 1974). Each animal was weighed and measured, then temporarily marked with a piece of brightly coloured tape attached to the tail, making the platypuses more visible to observers and to the video camera. Based on observations reported above and Bethge (2002), who reported a maximum foraging dive duration of 138 seconds, individuals were immersed for a maximum of 3 minutes before the trap was lifted to permit them to breathe. If they exited the trap prior to lifting, the elapsed time was recorded. The numbers of times each animal approached the platform below the escape hole was recorded. All animals were used only once in the experiment and remained in the trap for no more than 3 minutes.

Results

Table 3 shows the dimensions of the platypuses used, the time in the trap, the number of approaches to the platform below the escape hole, and whether or not individuals escaped. Only one juvenile male platypus managed to find the escape hole (after 30 seconds in the trap), but showed reluctance to leave the steel ring around the hole. It re-entered the body of the trap three more times before finally leaving the trap completely. This animal repeatedly relocated the escape hole after re-entering the trap, taking 30, 50 and 50 seconds respectively, before finally escaping. The other four trial animals failed to find the escape hole and were released after 2-3 minutes.

Contrary to expectation, platypuses (including the one which escaped) spent most of the time investigating the bottom or ends of the trap, rather than exhibiting surface/search behaviour. In fact, they seemed to actively avoid the platform area below the escape hole. All animals searched with their bills around the corners of the trap between the sides and ends. The video showed them frequently investigating the acute angled edge between the base of the entrance funnel and the sides of the trap. When released, all animals were observed to surface and appeared to be breathing heavily.

EXPERIMENT 5. Assessment of escape of platypuses from the modified carp traps

In Experiment 4, platypuses were observed continually searching for an escape hole around the corners of the trap. It was therefore decided to test the effectiveness of escape holes positioned around the base of the entrance funnel. Because the gap between the funnel and the sides of the trap was quite narrow at the base of the funnel, it was considered that most carp would be too large to access openings in this position. Experiment 5 tested the effectiveness of these modifications. The experiment was done in one pool on the Wingecarribee River on 27 November 2002 and then in four pools on the upper Shoalhaven River from 21-23 December 2002.

Methods

Every third mesh attached to the trap frame at the base of the funnel was released and tied back to provide 90 x 90 x 90 mm triangular openings (Fig. 4, top). In the initial trial in the Wingecarribee River these openings were made only in the upper half of the trap, but in the later trials in the upper Shoalhaven River, openings were made in both the upper and lower halves of the trap.

Fourteen platypuses were individually placed in the submerged trap as described in Experiment 4. Again observations were made of the number of times animals approached the platform below the escape

Table 4. Results of Experiment 5. Assessment of escape of platypuses from the modified carp trap. * not observed escaping but were not present in trap when it was lifted after 3 minutes; - escape holes only available in upper part of this trap.

Sex	Weight (g)	Length (cm)	Time in trap (sec)	Approaches to platform	Escape	Escape location
Female	850	43.0	85	1	Yes	-
Female	690	41.0	15	0	Yes	lower
Female	900	46.0	22	0	Yes	lower
Female	940	43.5	15	0	Yes	lower
Female	900	44.0	40	0	Yes	upper
Female	790	41.0	41	0	Yes	upper
Female	870	43.5	140	0	Yes	upper
Female	930	44.0	33	0	Yes	upper
Female	860	44.0	<180*	0	Yes	lower
Female	840	43.5	45	0	Yes	upper
Female	790	43.0	156	0	Yes	upper
Male	1850	55.2	35	1	Yes	-
Male	1740	52.0	<180*	0	Yes	lower

hole. Escapes through the triangular holes at the base of the entrance funnel were partitioned as being from the 'upper' or 'lower' openings in the trap. Some underwater video observations were made but the turbidity of the pools made viewing difficult. However, brightly coloured tape attached to the tails of the animals (see Experiment 4) usually permitted their movements in the trap to be observed. Again, if the platypus was not seen to escape, the trap was lifted from the water after a maximum of 3 minutes.

Results

Thirteen platypuses escaped from the openings around the base of the entrance funnel of the trap within 3 minutes (Table 4). As was observed in Experiment 4, all animals attempted to find an escape route around the bottom or ends of the trap. Another individual used in the initial trial located a hole inadvertently left at the bottom of the trap (which was sealed before subsequent trials). No preference was shown for escape location, with six animals exiting from the 'upper' and 5 from the 'lower' openings, where both were available (Table 4). One individual moved into the space between the platform and the escape hole but did not find the hole, submerging again and leaving the trap by one of the openings at the base of the entrance funnel. Only two individuals approached the platform at any time during their confinement in the trap. In two instances the platypuses could not be seen, but were no longer in the traps when they were lifted after 3 minutes. It was presumed that they had exited the lower holes, as they were not seen leaving the upper ones, which were visible to the observers.

DISCUSSION - Carp trap experiments

Experiment 4 indicated that the unmodified carp trap would probably result in significant mortality of platypuses if deployed in areas where their distribution overlaps that of carp. However, experiment 5 indicated that carp traps with appropriate escape holes could be used to reduce by-catch of platypuses. Platypuses over a size range of 690-1880 grams were able to exit quite quickly (15-156 seconds) through the 90 mm triangular openings in the modified carp trap.

It should be noted that the platypuses used in these experiments were not particularly large. There is considerable sexual dimorphism in the species, with the average male being around 75% heavier and 20% longer than females (Carrick 1995; Grant 1995; Connolly and Obendorf 1998). Individuals of up to twice the size of those used in current experiments are found in some mainland areas (especially west of the Great Dividing Ranges; Carrick 1995; Grant 1995) and in Tasmania males may reach up to three kg (Connolly and Obendorf 1998). Further experiments are required to determine the size of escape holes effective for larger platypuses. In the interim, the authors recommend triangular openings of 100 x 100 mm for east-flowing streams in New South Wales and openings of at least 120 x 120 mm for west-flowing streams in the state. Trials would also need to be carried out to assess the effectiveness of retaining captured carp in the presence larger escape holes.

The unexpected lack of surface/search behaviour in platypuses during Experiments 4 and 5 indicates the importance of field trials of fishing equipment with regard to specific wildlife species. The reason for the unexpected lack of surface/search behaviour in water can only be speculated upon. Platypuses frequently forage among dense woody debris and under submerged overhanging banks (Grant 1995 and personal observation). It may be that a behavioural response of moving down and/or sideways away from an obstruction during foraging may be of greater survival value than attempting to rise directly to the surface when seeking an escape route. No 'wedging' behaviour (Evans et al. 1994; Bethge et al. 2001; Bethge 2002; Experiment 3) was exhibited by animals in the carp traps. Rather, all individuals searched constantly for an escape route.

GENERAL CONCLUSIONS

The results of the literature reviewed and experiments presented in this paper indicate that any fishery in freshwaters of New South Wales based on the use of traps should not be operated as an unregulated fishery (Figure 1) if reducing platypus mortality is a priority. By-catch minimisation has been possible in the eel fishery by a combination of closures of some inland waters and by modifications to provide an airspace in traps used in farm dams and impoundments. Exclusion devices (e.g. grids across the entrance funnels of traps) do not provide a commercially viable option for reducing the by-catch of platypuses in eel or yabby traps. Banning of yabby traps from areas where platypuses occur is currently the only available means of avoiding by-catch mortality in this fishery. The commercial and recreational yabby fisheries in New South Wales are currently restricted to waters where platypuses do not commonly occur or are very uncommonly reported. Trap modifications, which permit the escape of platypuses, appear to be the most feasible means of by-catch minimisation in the use of traps to capture carp.

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