Drifting fish larvae in Murray-Darling Basin rivers: composition, spatial and temporal patterns and distance drifted

Paul Humphries[1] and Alison J. King[2]

[1] Cooperative Research Centre for Freshwater Ecology, Department of Biological Sciences, Monash University, c/- Murray-Darling Freshwater Research Centre, PO Box 921, Albury, NSW 2640, Australia.

[2] Arthur Rylah Institute for Environmental Research, PO Box 137, Heidelberg, Victoria, 3084, Australia.

INTRODUCTION

Larvae and juveniles of many riverine fish species throughout the world are known to undergo downstream displacement, or drift (e.g. Brown and Armstrong 1985, Juradja 1998, Robinson *et al*. 1998). In some species, the drift of young fishes is regular and is considered to be an important component of the life cycle of many species. In contrast, other species only appear in the drift during catastrophic events such as floods, where there are displaced from their nursery habitats (Harvey 1987).

Despite the numerous overseas studies on larval drift, it is still not clearly understood why some species of young fish drift. Suggested reasons include: avoidance of predation and/or competition, active searching for favourable nursery habitats, active feeding on invertebrate drift and nocturnal disorientation resulting in accidental displacement (see Armstrong and Brown 1983). Drifting is also likely to be an important dispersal mechanism, facilitating the mixing of propogules and genes throughout the population.

Although it is well established that a number of Murray-Darling fish species undergo significant adult migrations and movements, relatively little work has been conducted on the movement of young fishes (see Humphries *et al*. 1999). This paper brings together results from a number of projects that have been conducted within the Cooperative Research for Freshwater Ecology's Campaspe Flow Manipulation Project, and aims to:

- describe how widespread larval drift is in Murray-Darling Basin fishes, using a long-term data set from two rivers in the southern region of the Basin,
- describe patterns of larval drift throughout the year;
- classify species into drifting types based on their occurrence in the drift,
- and report preliminary results of an investigation into the distance drifted by Murray cod larvae.

METHODS

Study location

Sampling was carried out in the Campaspe and Broken Rivers, northern Victoria. For detailed descriptions of the history of hydrological development of the two rivers see Humphries *et al*. (2002). Briefly, the Campaspe River is a tributary of the Murray River and, since the early 1960s, its flow has been altered for irrigation purposes. The entire river downstream of Lake Eppalock experiences reduced duration of high winter flows due to the capture of water for later irrigation release. Additionally most of the river downstream of the Lake experiences enhanced summer flows. Records indicate that the Campaspe River once supported approximately 20 species (Humphries & Lake 2000), including Murray cod, *Maccullochella peelii peelii*, silver perch, *Bidyanus bidyanus*, freshwater catfish, *Tandanus tandanus*, and golden perch, *Macquaria ambigua*, and was known to be one of the best rivers for Macquarie perch, *Macquaria australasica*, in the state of Victoria (Anonymous 1973). Recent evidence (Humphries & Lake 2000), however, suggests that the fish fauna is highly degraded, and dominated by the introduced species common carp, *Cyprinus carpio* and European perch, *Perca fluviatilis*. Periodic stockings of Murray cod and golden perch, probably help to sustain populations of these two species

(Department of Natural Resources and Environment, unpublished data), but there is now no sign of the once abundant Macquarie perch.

The Broken River is a tributary of the Goulburn River and is only mildly regulated. Two weirs exist downstream of Benalla, in the section of river studied. Historically, the same species of fish would probably have occurred naturally in both the Campaspe and Broken Rivers (Humphries & Lake 2000). The dominant instream habitat structure in both rivers is large woody debris (or 'snags') mainly from riparian river red gums, *Eucalyptus camaldulensis*, and stands of aquatic macrophytes, comprising mostly common reed, *Phragmites australis*.

Collection of larvae

Sampling was carried out over 7 years, usually monthly, from October 1995 until April 2001, at 6 reaches in the Campaspe River between Lake Eppalock and Echuca and 4 reaches in the Broken River between Benalla and Shepparton. Drift sampling was conducted using a 0.5 m diameter, 1.5 m long, conical shaped 500 mm mesh net. One drift net was set just before dusk in each reach, usually where a constriction in the channel funnelled a large amount of the flow, and left overnight. The volume of water filtered was estimated using a General Oceanics® flow meter set in lower third of the net, enabling numbers of larvae to be adjusted to number of larvae per 1000m^3.

Five modified quadrafoil light traps were set randomly in still or slow flowing habitats in each pool and run reach before dark and retrieved early the next day (see Humphries *et al*. 2002 for further details). All samples were preserved in 95% ethanol immediately, later sorted in the laboratory and the larvae counted and identified. Identifications were made using a variety of published descriptions of larvae, personal observations and collecting successive larval collections over the sampling years.

Sampling of drifting Murray cod larvae

To investigate the diel patterns in abundance of drifting Murray cod larvae, two 500 µm mesh nets were set and retrieved every 4 h at Goomalibee between 16:30 on 2 December 1997 and 16:30 the following day. The nets were deployed and retrieved in the same manner as described for the monthly sampling described above, except that nets were left in for 4 h. Results are expressed as raw abundances and abundances adjusted to larvae per 1000m^3.

In an effort to estimate the distance that Murray cod larvae drift downstream in a single night, two 500 mm mesh drift nets were placed at 0 (station 1), 20 (station 2), 200 (station 3) and 2000 m (station 4) stations downstream from Goomalibee Bridge on the Broken River during the nights of 12-14 December 2000. Prior to sampling, the average time taken for 50 oranges to drift 500 m through the same reach was determined, and was used to estimate the average current speed. Drift nets were deployed in a manner designed to sample approximately the same 'slug' of water at each station. Thus, nets were set at station 1 from 20:30-23:30, those at station 2 from 20:31-23:31, those at station 3 from 20:42-23:42 and those at station 4 from 22:30-01:30.

RESULTS

Composition and abundance

Overall, the larvae of eight species of fish were collected in drift samples (**Figure 1**). The drift fauna in the Broken River was dominated by Murray cod in four of the seven years, with common carp the most abundant species collected in 1998 and 2001, and Australian smelt contributing more than 95% to the total number in 2000. The results for this last year were anomalous and reflected the fact that large numbers of Australian smelt were flushed from weir pools and other still-water habitats during high flows over the spring of that year. The larval fish fauna of the Campaspe River comprised more than 95% flathead gudgeon in each year of the study, except in 1996, when Australian smelt, carp and Gambusia all contributed significantly. This was the wettest year of the sampling period causing Lake Eppalock spill, and no doubt larvae of some species, which would normally not drift, were flushed from backwaters and entrained in the current.

Temporal patterns in larval drift

Composite data from the Campaspe and Broken Rivers indicated that larvae occurred in the drift from August until March in most years (**Figure 2**). Australian smelt and flathead gudgeon were collected for the longest period, up to 7 months. Overall, the peak time for drifting larvae was between October and December each year. Numbers of Australian smelt peaked in September in the Campaspe River, but in November in the Broken River, mainly due to a large number of Australian smelt captured in the November 2000 sampling. Common carp and Murray cod were present in the drift during the same months in the Broken River, peaking in November. Flathead gudgeons were by far the most abundant species occurring in the drift, with abundances peaking usually in December in the Campaspe River.

Categories of drifters

Composite data from light trap and drift net samples from both rivers was used to explore whether some species were predominantly found in still habitats or flowing water habitats. A number of species were collected in both sampling methods (**Figure 3**). Murray cod were predominantly captured in drift samples, whereas Australian smelt, carp gudgeons, rainbowfish and galaxiids were only found in light trap samples.

Drifting behaviour of Murray cod larvae

Diel sampling of Murray cod larvae on 2 December 1997, indicated that the raw abundance of larvae differed significantly with time of day (df=11,5; ms=0.287, $p<0.05$), although, this was not true for the abundance adjusted to numbers of larvae per $1000m^3$ (**Figure 4**). Nevertheless, few larvae were collected before dark on 2 December and in the morning of 3 December.

Drift sampling conducted on the 12 December 2000, found no Murray cod larvae present in the 0 or 20 m sites, however approximately 20 individuals were captured at each of the 200 and 2000 m sites (**Figure 5a**). The larvae in each of these samples had extremely tight age distributions (**Figure 5b**), which may indicate that they were from the same brood. If this was the case, this preliminary investigation suggests that Murray cod larvae can drift at least 1800 m in a 3 hour period.

DISCUSSION

Prevalence of larval drift in the Broken and Campaspe Rivers

Of the 11 species collected as larvae in the Broken and Campaspe Rivers, eight species were captured in the drift (Humphries *et al*. 2002). Pavlov (1994) classified drifters as active, passive and active/passive. Active drifters orientate downstream and actively move in and out of the current. Passive drifters are usually entrained in the current due to high flows or the loss of orientation because of low light levels and are haphazardly orientated. The third group tend to be orientated upstream, have a degree of capability to determine how far and where in the river channel they drift. It is possible that the larvae of all riverine fish will drift passively if discharge is high enough and occurs at the right (or wrong) time. Therefore, it may be more informative to ask if drifting is a necessary part of the life cycle, if it is an advantage in some situations or for some components of the population, but not for all, or if it is never part of the life cycle. Furthermore, we have no knowledge of the orientation of larvae of the species that we have collected in the drift, and therefore we have classified the species based solely on their occurrence in drift samples and their abundance relative to those in other habitats and using other sampling methods. We have designated three broad categories of drifters (**Table 1**):

1. Obligate: those species that occur predominantly in the drift and are rarely collected elsewhere and for which we presume drifting is a necessary part of their early life history;
2. Facultative: those species which occur in the drift and in still or slow-flowing habitats, but for which drifting may facilitate dispersal; and
3. Non-drifters: those species that are only rarely found in the drift and, when they do, it is likely to be because they are unwittingly entrained in currents.

Table 1. Categorisation of Murray-Darling fish species based on their use of the drift as larvae and/or juveniles.
** introduced species*

Category	Species
Obligate	Murray cod
Facultative	Australian smelt Common carp* Flathead gudgeon
Non-drifters	Crimson-spotted rainbowfish River blackfish *Galaxias spp.* European perch (redfin)* Gambusia* Carp gudgeons

Murray cod is probably the only obligate drifter of the species collected in drift samples (**Table 1**). It was only rarely caught in light traps and fyke and seine nets. Trout cod are also highly likely to be obligate drifters, although this still requires confirmation, as it is dependant upon confident identifications between the two cod species as larvae in some systems such as the Murray River. Other species thought to be obligate drifters, but which were not collected as part of this study, are golden and silver perch. These species have been very rarely captured as larvae, and further research is required to confirm the drifting phenomenon of these species. Australian smelt, common carp and flathead gudgeons were collected in large numbers at times in drift samples, however, in each of these cases, they were also collected in light traps in backwaters of runs and in pools. Classifying flathead gudgeons was difficult, and, because of their huge abundance in drift samples, might be considered obligate drifters. But their occurrence in pools, where they are planktonic as early stage larvae, suggests that drifting is not a requirement of their early life history. Non-drifters include some species never found in the drift and others occasionally found in drift samples. As larvae these species tend to be associated with still or slow-flowing habitats and are probably only accidentally entrained in the water column.

Why and how larvae drift

The early life history stages of animals often disperse from the breeding site. This can be to reduce competition, avoid cannibalism, move to more appropriate rearing habitats, or all three. Competition, for a species like Murray cod, where larvae stay together for many days in a 'ball', being guarded by the male parent, is likely to be high once all of their yolk sac is absorbed. Cannibalism is also known to be widespread among fish species and, in some cases, affect levels of recruitment. However, for all species drifting is likely disperse larvae over a much wider area than if drifting did not occur. This would aid in colonisation of reaches where spawning may not occur and promotes genetic diversity.

It is clear from our diel sampling that Murray cod have the ability to regulate when they drift. This is common amongst drifting larvae (e.g. Brown & Armstrong 1985, Pavlov 1994, Copp *et al*. 2002), with even very small larvae capable of moving into and out of the drift at will (Franzin & Harbicht 1992). Murray cod and other larvae may also be able to determine their position in the river channel. Studies have indicated either a degree of capability of larvae to determine where they are in a river or that the shape of larvae and eggs determines their distribution (Pavlov 1994, Copp *et al*. 2002).

Few studies have attempted to determine how far fish larvae drift in rivers. This is understandable, because of the difficulties in following a batch of tiny fish in an often turbid environment. Our stratified sampling in the Broken River suggested that larvae could drift approximately 2 km in 3 h. Sampling in the following year, suggested that larvae could drift at least 4 km in one night during summer

(Humphries, unpublished data). Humphries (in review) has estimated that Murray cod larvae can drift for approximately 5-7 days, which, assuming that they only drift at night and they drift 4 km per night, translates to about 20-28 km in total. Although it is possible that some larvae drift even further, especially if discharge is high, this would mean, in the Broken River, that they are retained within the same general area in which they were spawned.

CONCLUSION

Research into the early life stages of Murray-Darling fish species has increased in recent years, however the potential effects of river regulation on drifting fish larvae are at this stage still purely speculative, but could include:

- Removal of drifting larvae from the river into irrigation channels;
- Disruption of downstream dispersal of larvae by weirs;
- Artificially high summer irrigation flows may drown out favourable nursery habitats (such as slackwaters) for some species;
- Washout of larvae from favourable nursery habitats from rapid alterations in discharge causing catastrophic drift of typically non-drifting species and possible death.

Further research is urgently required to elucidate the potential effects and overall significance of water extraction and its associated infrastructure and river management on the survival and subsequent recruitment of the early life stages of Murray-Darling fish species.

RESEARCH RECOMMENDATIONS

- Establish the abundance and significance of drifting eggs, larvae and juveniles moving into unfavourable habitats in irrigation systems
- Determine the relative abundance of drifting eggs, larvae and juveniles being extracted directly from the river through irrigation pipes.
- Conduct further research into the distance drifted of key species such as Murray cod,
- Determine the influence of weirs (movement past the weir wall and through power stations) and weir pools have on downstream dispersal of young stages of Murray-Darling fishes.
- Determine key spawning and recruitment areas within the Basin and establish whether significant barriers exist for dispersal.

References

Anonymous 1973. Native fish in the Campaspe and Coliban Rivers. *Freshwater Fisheries Newsletter*: 5, 18-19. (Fisheries and Wildlife Victoria, Australia).

Armstrong, M.L., & Brown A.V. 1983. Diel drift and feeding of channel catfish Alevine in the Illinois River, Arkansas. *Transactions of the American Fisheries Society* 112, 302-7.

Brown, A.V., & Armstrong M.L. 1985. Propensity to drift downstream among various species of fish. *Journal of Freshwater Ecology* 3, 3-17.

Copp, G.H., Faulkner, H., Doherty, S., Watkins M.S., & Majecki, J. 2002. Diel drift behaviour of fish eggs and larvae, in particular barbel, Barbus barbus (L.), in an English chalk stream. *Fisheries Management and Ecology* 9: 95-103.

Franzin, W.G. & Harbicht S.M. 1992. Tests of drift samplers for estimating abundance of recently hatched walleye larvae in small rivers. *North American Journal of Fisheries Management* 12: 396-405.

Harvey, B.C. 1987. Susceptability of young-of-the-year fishes to downstream displacement by flooding. *Transactions of the American Fisheries Society* 116, 851-5.

Humphries, P (in review) Spawning time and early life history of Murray cod, *Maccullochella peelii peelii* (Mitchell) in an Australian river.

Humphries, P., & Lake P.S. 2000. Fish larvae and the management of regulated rivers. *Regulated Rivers: Research and Management* 16: 421-32.

Humphries, P., King A.J., & Koehn J.D. 1999. Fish, flows and flood plains: links between freshwater fishes and their environment in the Murray-Darling River system, Australia. *Environmental Biology of Fishes* 56, 129-51.

Humphries, P., Serafini L., & King A.J 2002. River regulation and fish larvae: variations through space and time. *Freshwater Biology* 47: 1307-31.

Juradja, P. 1998. Drift of larval and juvenile fishes, especially *Rhodeus sericeus* and *Rutilus rutilus*, in the River Morava (Danube basin). *Archiv für Hydrobiologie* 141: 231-41.

Pavlov, D.S. 1994. The downstream migration of young fishes in rivers: mechanisms and distribution. *Folia Zoologica*. 43: 193-208.

Robinson A.T., Clarkson, R.W., & Forrest, R.E. 1998. Dispersal of larval fishes in a regulated river tributary. *Transactions of the American Fisheries Society*: 127, 772-786.

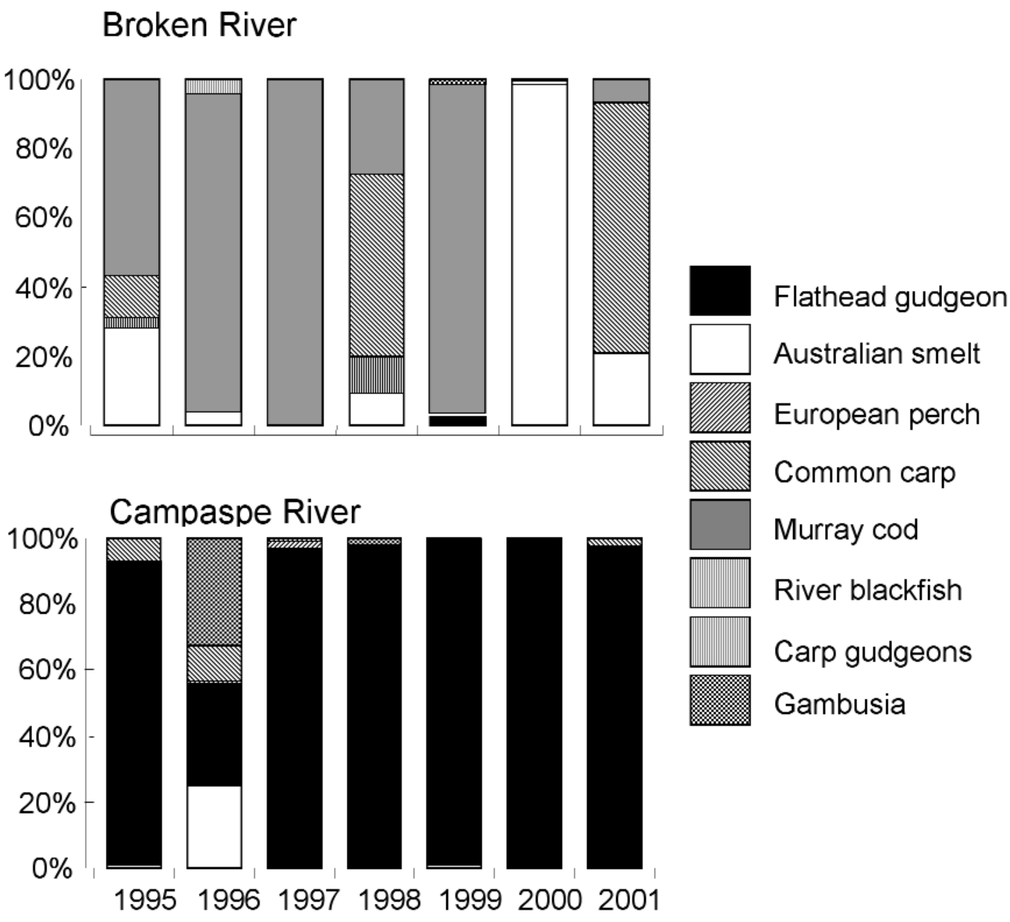

Figure 1. Species composition sampled in drift nets from the Broken River and Campaspe River from 1995 - 2001.

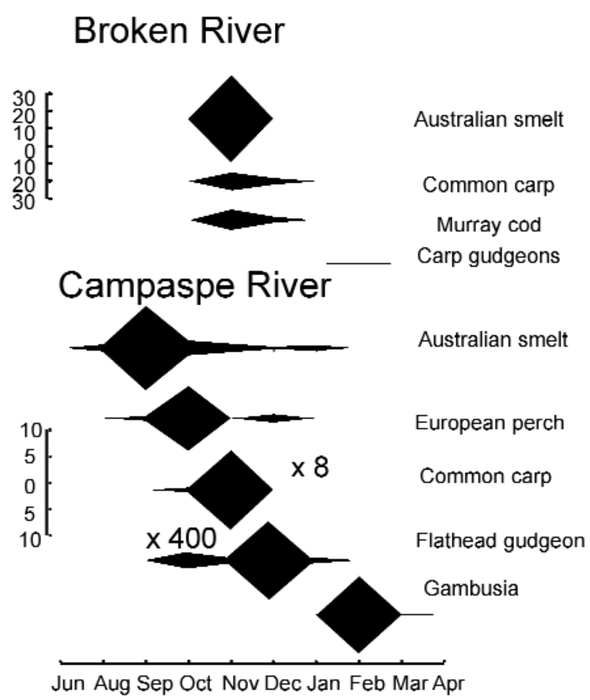

Figure 2. Temporal patterns in larval drift from the Broken and Campaspe Rivers.

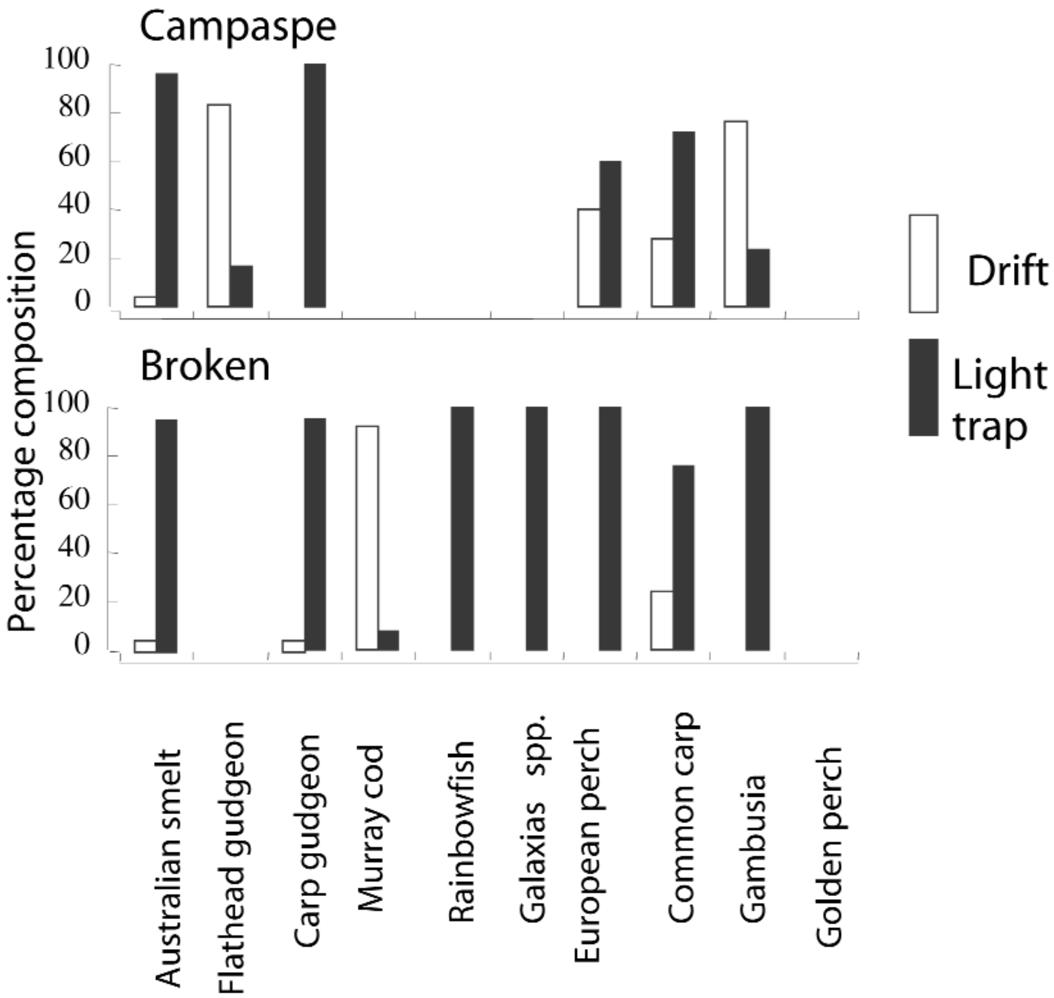

Figure 3. Per cent species composition captured in drift nets and light traps in the Broken and Campaspe Rivers.

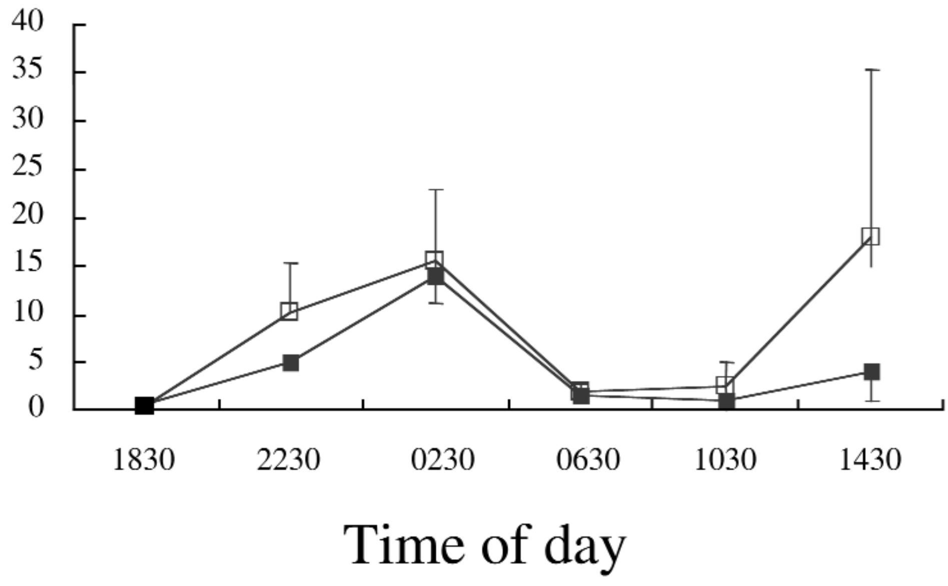

Figure 4. Abundances of Murray cod larvae collected during diel sampling in the Broken River on 2nd December 1997.

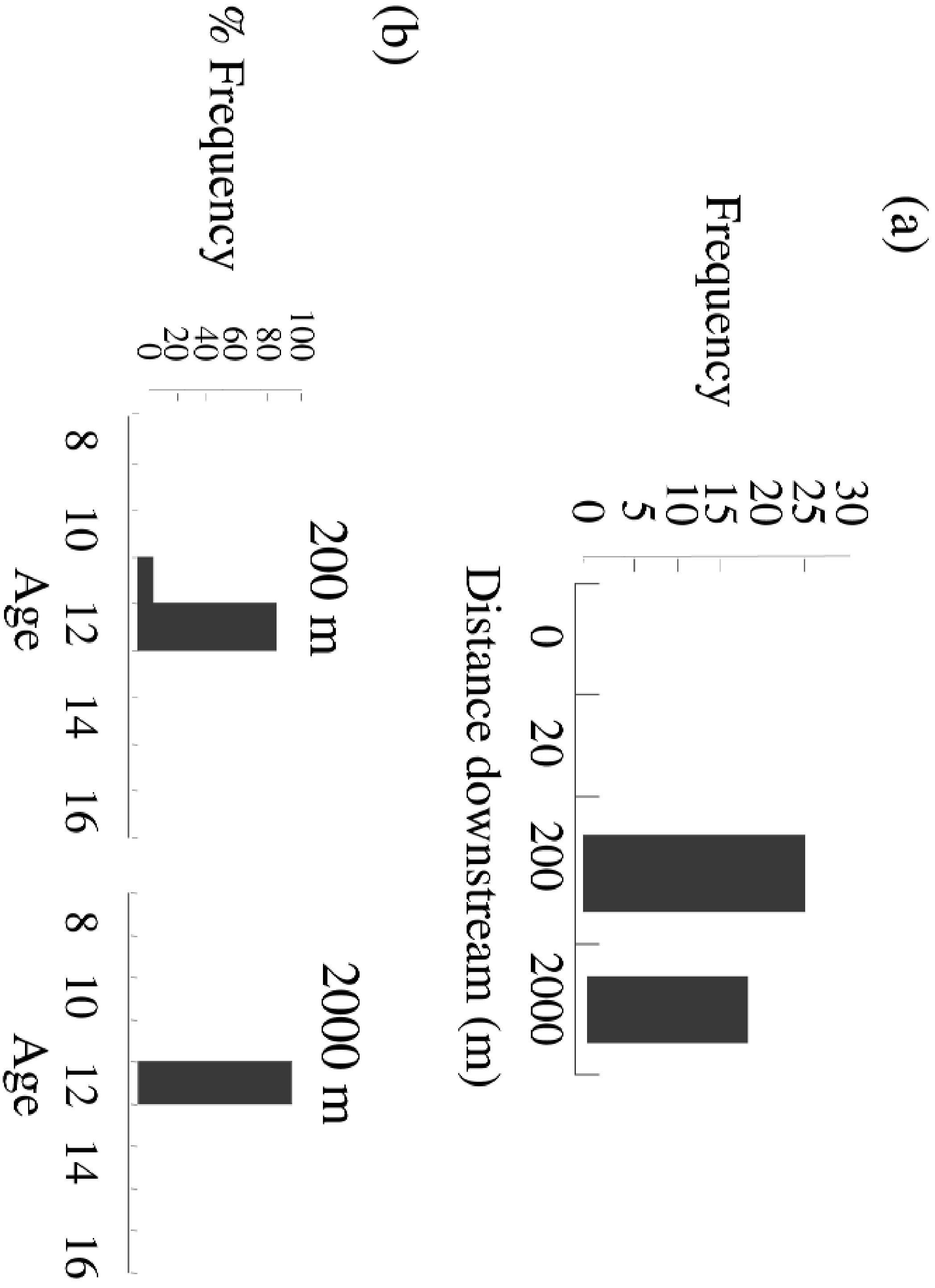

Figure 5. (a) Number of Murray cod larvae and (b) age collected during distance drifted experiment in the Broken River