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Population Dynamics of Chironomid Larvae (Diptera: Chironomidae) in Earthen Fish Ponds in South-eastern Australia

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Abstract

The chironomid community of ephemeral earthen ponds used to rear juvenile percichthyid fish in south-eastern Australia was described for the first time. Seventeen chironomid taxa were collected with genera *Chironomus*, *Polypedilum* and *Procladius* the most common. Chironomid densities reached a maximum of 27,450 ind. m^{-2}. *Polypedilum* was most abundant, followed by *Chironomus* and then *Procladius*. *Polypedilum* and *Procladius* appeared to prefer the shallower sections of the ponds. Approximately 33% of specimens from the "Orthocladiinae spp." taxal group were encased in a "cocoon" constructed of sand grains. Marked variations in the abundance of chironomid taxa were observed between months and seasons. In the first half of the season (November-December), *Chironomus* was most abundant and common, whereas in the latter half of the season (January-February) *Polypedilum* was most abundant. Both *Polypedilum* and *Procladius* were more abundant in the first year than in the second year of the study.

Introduction

The family Chironomidae (Diptera) in Australia contains more than 200 species in 86 genera (Colless and McAlpine, 1991). In Australia, larval chironomids have often been included in faunal studies of aquatic-macro-invertebrates in rivers, streams and wetlands, but specific studies of chironomid communities and population dynamics are limited. Descriptions of chironomid assemblages have been undertaken in floodplains along the Murray River (e.g. Hillman and Nielsen, 1995; Suter et al. 1995). Maher and Carpenter (1984) reported densities of larvae in the order of 70,000 ind. m^{-2} in waterfowl breeding habitats in south-western New South Wales. Aspects of the biology and management of pestiferous species of flooded rice fields, especially *Chironomus tepperi* Skuse, have been studied (e.g. Stevens 1994; Stevens 1995; Stevens and Warren, 2003). Chironomids have also been used in biological monitoring and river health programs, and as indicators of pollution (Creagh, 1993; Rosenberg and Resh; 1993; Chessman, 1995).

Production of fish fingerlings for stock enhancement programs relies to a large extent on the extensive rearing of these fish, in static, fertilised earthen ponds (nursery ponds) (eg. Geiger, 1983; Anderson and Tave, 1993). In south-eastern Australia, numerous fish hatcheries and nursery pond systems have been established for production of several important freshwater

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native fish species, especially percichthyids (*Maccullochella* spp. and *Macquaria* spp.), to support stock enhancement programs and aquaculture. Due to the seasonality of fingerling production, these nursery ponds are ephemeral in nature, being filled with water during the warmer months of the year (October-April) and left dry over the cooler months. Chironomid larvae are ubiquitous in the benthos of these ponds and often become quite abundant, forming a large proportion of the macro invertebrate biomass (Ingram et al. 1997). Not surprisingly, chironomid larvae are an important component in the diet of the fingerlings, having been identified from the stomach contents of juvenile percichthyids reared in ponds (Ingram and De Silva, 2007; Ingram, 2009). Yet, despite their apparent importance, there have been no previous attempts to study chironomid larvae in freshwater fish ponds in Australia, whereas in Europe such studies are more common (e.g. Matena, 1989; Wahab et al. 1989; Janecek, 1995).

The aim of the present study was to describe changes in species composition and abundance of chironomid larvae in earthen fish ponds used to rear juvenile percichthyid fish.

Material and Methods

The present study was undertaken in four earthen nursery ponds located at the Department of Primary Industries, Snobs Creek facility (henceforth referred to as Snobs Creek) (37^{o}14'S; 145^{o}55'E). All ponds used during this study were specifically constructed for the rearing of juvenile fish which are released into the wild for recreational fishery enhancement and conservation purposes (Rowland, 1986). Ponds were rectangular in shape and ranged in surface area and volume from 900 to 2,800 m^2 and 670 to 1,760 m^3, respectively. Each pond had a large shallow section (0.5 – 1.0 m deep) covering approximately 3/4 - 2/3 of the pond surface area, and a small deep section (1.5 - 2.0 m in depth) at one end. The source of water entering all ponds was diverted via a pipeline from a relatively oligotrophic, cool, mountain stream.

Species composition and abundance of chironomid larvae and pupae were determined from samples collected from the substrate of four ponds during the southern hemisphere spring and summer period (between November and February) over two consecutive seasons (1992/1993 and 1993/1994). Each pond filling was assigned a trial number. A pond filling represented the period from the time a pond was inundated with water to the time when it was completely drained. A total of 13 pond fillings were undertaken over the two seasons. The four ponds were initially filled between 2 November and 8 December in each season, while three of the ponds in the first season and two of the ponds in the second season were dried and refilled a second time between 24 December and 8 February. Prior to inundation at the beginning of each season the ponds were dried and the substrate was rotary hoed to a depth of 100-120 mm and raked smooth with tyne harrows. Due to the low alkalinity of the water source, agricultural ground limestone was applied to the dry ponds at a rate of 500 - 2,000 kg. ha^{-1} prior to inundation. After inundation, ponds were fertilised with both ammonium sulphate and mono ammonium phosphate, each at a rate of 10-30 kg.ha^{-1} every 7-28 days. Water level in each pond was maintained by regular addition of water. Ponds were lightly stocked with fry (8-15 fry m^{-2}) by day 12-17.

With the aid of a boat, four samples of substrate were collected from randomly selected sites within each pond weekly. Samples were collected with a coring device, which was constructed of PVC and aluminium tubing. This device removed a core of mud 4.5 cm in diameter and 7.0 cm in length. Macrobenthos, including chironomids, were separated by repeatedly suspending each core sample in water and decanting the supernatant into a 250 µm Endecott test sieve. This technique is reported to separate the majority of benthic macroinvertebrates from sediment samples (Kajak and Warda, 1968; Maitland and Hudspith, 1974). The sample retained by the sieve was then preserved in 5% buffered formalin for later sorting. The preserved samples were sorted in a 50 mL sorting tray and examined under a dissecting microscope at 80x magnification. Chironomid larvae and pupae were counted and, where possible, the total length and head capsule length were measured before being mounted on a microscope slide in polyvinyl alcohol (Cranston, 1994). All other macroinvertebrates were recorded and identified using keys in Ingram et al. (1997).

Additional information on chironomids was obtained from weekly sampling of zooplankton in the open water of the ponds, using an integrated tube sampler (Graves and Morrow, 1988), and the examination of the gut contents of fish reared in the ponds (Ingram and De Silva, 2007). Fish: Murray cod (*Maccullochella peelii peelii* (Mitchell)), trout cod (*Maccullochella macquariensis* (Cuvier)) and Macquarie perch (*Macquaria australasica* Cuvier) were collected weekly from ponds using a combination of plankton net, sledge and mesh bait traps. Five fish from each sampling period for each fish species were killed in an overdose of anaesthetic and preserved in 5% buffered formalin. Preserved fish were later dissected for diet analysis. The contents of the stomach were transferred to a 10 mL capacity sorting tray and examined at 20x magnification with a dissecting microscope. All chironomids were counted and measured as described above.

Mounted larvae were identified to lowest possible taxonomic level using keys provided in Cranston (1994) and Cranston (1997), and the mandible length measured with a calibrated eyepiece micrometer. The relationship between head capsule length and mandible length, or length frequency distribution of head capsule length and mandible length were used to determine larval instars for common chironomid species. These were *C. tepperi*, *Polypedilum nubifer* (Skuse, 1889), and *Procladius paludicola* Skuse.

Results

Chironomid larvae and oligochaetes were the most frequently encountered and common macroinvertebrates in the benthos of the ponds. Chironomid larvae occurred in 96% of the samples and oligochaetes were present in 79% of the samples. Oligochaetes densities ranged from 0 to 51,590 ind. m^{-2} (mean 7,407 ind. m^{-2} $\pm$ 1,053 standard error (s.e.)). Nematodes were abundant and present in all samples with densities in some samples exceeding 112,600 ind. m^{-2}, but these figures were an underestimation of densities as many of the smaller species of nematode would not have been retained on the 250 µm sieve used to process samples. Ostracods, cyclopoid copepods and gastropods (*Physa acuta* Draparnaud 1805) were frequently observed in

samples. A complete list of other invertebrates collected from nursery ponds at Snobs Creek is presented in Ingram et al. (1997).

Species composition and abundance

A total of 3,076 chironomid larvae and 59 chironomid pupae, representing 17 taxa groups, were collected from core samples and the stomachs of fish during sampling of ponds (Table 1). Taxa belonging to the subfamily Chironominae were more abundant and common than taxa from the other sub-families combined. The more common taxa collected were *Chironomus* (*C. tepperi*) (28%), *Polypedilum* (*P. nubifer*) (26%), *Procladius* (*P. paludicola)* (15%) and Orthocladiinae spp. (8%), that together accounted for 77% of all larvae collected (Table 1). Chironomid pupae were less frequently collected than larvae, representing less than 2% of the total number of chironomids collected during the study. Chironomid larvae were not frequently encountered in the open water of the ponds, occurring in 12% of plankton samples. When present in plankton samples, densities reached a maximum of 12 ind. L^{-1} (mean 3 ind. L^{-1}).

Table 1. Number and percentage of chironomid larvae and pupae collected from nursery ponds (core samples and the stomachs of fish) at Snobs Creek**.**

	LARVAE						PUPAE		
Taxa	Ponds		Fish stomachs		Total		Ponds	Fish stomachs	Total
	No.	%	No.	%	No.	%	No.	No.	No.
Chironominae									
Chironomus tepperi Skuse	659	30	225	25	884	28	7	10	17
Cladopelma sp.	83	4	5	1	88	3	0	2	2
Cladotanytarsus sp.	0		2	<1	2	<1			0
Coelopynia pruinosa Freeman	44	2	0		44	1			0
Cryptochironomus sp.	49	2	21	2	70	2	1	0	1
Dicrotendipes sp.	0		2	<1	2	<1			0
Kiefferulus martini Freeman	8	<1	95	11	103	3			0
Kiefferulus "tinctus"	11	1	15	2	26	1			0
Paratanytarsus sp.	27	1	50	6	77	2	2	0	2
Polypedilum nubifer (Skuse)	616	28	206	23	822	26	2	2	4
Riethia sp.	0		1	<1	1	<1			0
Tanytarsus spp.	45	2	35	4	80	3			0
Orthocladiinae									
Cricotopus sp.	0		2	<1	2	<1			0
Thienemanniella sp.	1	<1	0		1	<1			0
Orthocladiinae spp.	252	12	0		252	8			0
Tanypodinae									
Ablabesmyia notabilis Skuse	8	<1	4	<1	12	<1	0	1	1
Procladius paludicola Skuse	291	13	182	20	473	15	0	12	12
Unidentified	91	4	46	5	137	4	5	15	20
Total	2,185		891		3076		17	42	59

Chironomid larvae occurred in the stomach contents of 55% of Macquarie perch, 70% of Murray cod and 91% of trout cod sampled. Chironomid pupae occurred in the stomach contents of 23% and 22% of Murray cod and trout cod, respectively, but of only 3% of Macquarie perch. Ten of the 17 taxa were collected from both core samples and the stomachs of fish (Table 1). *Coelopynia pruinosa* Freeman, Orthocladiinae spp. and *Thienemanniella* sp.

were collected from core samples only, whereas *Cladotanytarsus* sp., *Cricotopus* sp., *Dicrotendipes* sp. and *Riethia* sp. were collected from the stomachs of fish only (Table 1). Overall, *Kiefferulus martini* Freeman was more often collected in the stomachs of fish (11% of chironomids collected) than from core samples (<1% of chironomids collected) (Table 1).

Taxa belonging to the Orthocladiinae were less abundant than other subfamilies. One group, the "Orthocladiinae spp.", was of particular interest as 33% of all specimens collected were encased in a "cocoon", a capsule constructed of sand grains cemented together. Cocoons were approximately 0.53 – 0.81 mm (mean 0.65 mm $\pm$ 0.01 s.e.) in diameter and grain sizes were 12 – 83 µm (mean 45.6 µm $\pm$ 5.7 s.e.) in diameter. Orthocladiinae spp. were collected from ponds as early as day 2 (both in cocoons and free living). For each month of sampling, the proportion of larvae that were cocooned was 8, 47, 22 and 60% for November, December, January and February respectively. Identification of these specimens was not possible, though P.S. Cranston (*pers. comm.*) suggested there may have been two undescribed species (cf. *Mesosmittia*/*Parasmittia*) in this taxa group.

Mean densities of chironomids from 13 separate pond fillings are presented in (Figure 1). Larval densities ranged from zero to a mean maximum of 27,470 ind. m^{-2} (overall mean 4,379 ind. m^{-2}) (Table 2), however, densities were mostly between 0 and 10,000 ind. m^{-2} (Figure 1). Most taxa were first collected in samples during days 7-14 and densities generally peaked between the day 21 and day 42 (Table 2, Figure 1).

Table 2. Densities of chironomid larvae collected from nursery ponds over two consecutive seasons at Snobs Creek.

Taxa	Percent of samples in which species present	Density (ind. m^{-2})			Day[1] first appeared in samples	Week[2] of first peak in density
		Maximum	Mean (all samples)	Mean (when present)	(mean day)	(mean week)
Ablabesmyia notabilis Skuse	5	670	15	335	11 (26)	3-5 (5)
Chironomus tepperi Skuse	38	12,060	978	2,542	9 (17)	2-5 (3)
Cladopelma sp.	29	2,680	136	464	10 (23)	3-5 (4)
Coelopynia pruinosa Freeman	12	1,340	64	523	22 (29)	3-6 (4)
Cryptochironomus sp.	26	1,005	106	406	10 (21)	3-5 (4)
Kiefferulus martini Freeman	5	670	14	263	31 (37)	5-5 (5)
Kiefferulus "*tinctus*"	5	1,340	26	487	11 (27)	3-7 (5)
Orthocladiinae spp	55	7,035	275	504	2 (14)	1-5 (3)
Paratanytarsus sp.	10	838	35	346	13 (21)	2-6 (4)
Polypedilum nubifer (Skuse)	54	19,430	1,462	2,715	5 (21)	1-5 (4)
Procladius paludicola Skuse	71	6,030	729	1,030	10 (14)	3-5 (4)
Tanytarsus spp.	18	1,675	88	477	5 (23)	3-5 (4)
Thienemanniella sp.	1	335	3	335	43	7
Total chironomids	96	27,470	4,379	4,554	2 (12)	1-5 (3)

1. Days after pond inundation. 2. Weeks after pond inundation

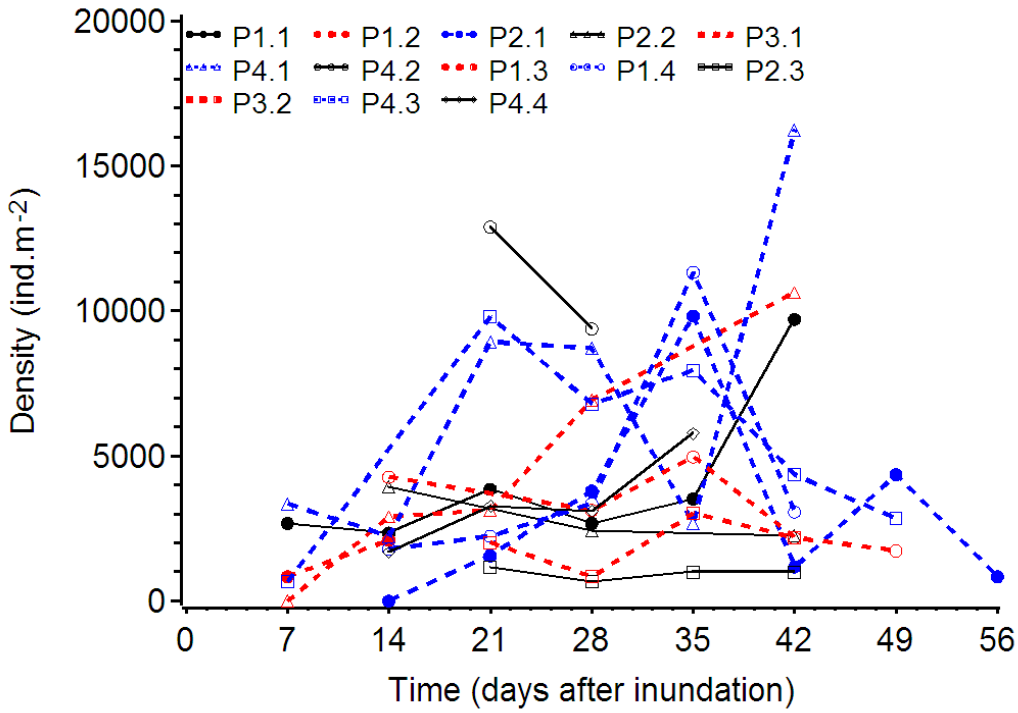

Fig. 1. Mean densities of chironomids recorded from 13 fillings of four nursery ponds

The four most abundant taxa were *Polypedilum*, *Chironomus*, *Procladius* and Orthocladiinae spp. (Table 2). *Polypedilum* was more abundant than any other taxon with densities reaching a maximum of 19,430 ind. m^{-2} (mean 1,462 ind. m^{-2}), while *Chironomus* reached a maximum density of 12,060 (mean 978 ind. m^{-2}). However, *Procladius* was encountered in more samples (71%) than any other taxon (Table 2).

Densities of *Chironomus* were higher in the middle section of the ponds than either the deep or shallow sections (Figure 2a). In contrast, the densities of both *Polypedilum* and *Procladius* were generally higher in the shallow section (Figure 2b and 2c). Densities of Orthocladiinae spp. were highly variable but did not appear to show a preference to water depth (Figure 2d). Total chironomid densities were generally highest in the shallower section of the ponds, followed by the middle and then the deep section (Figure 2e).

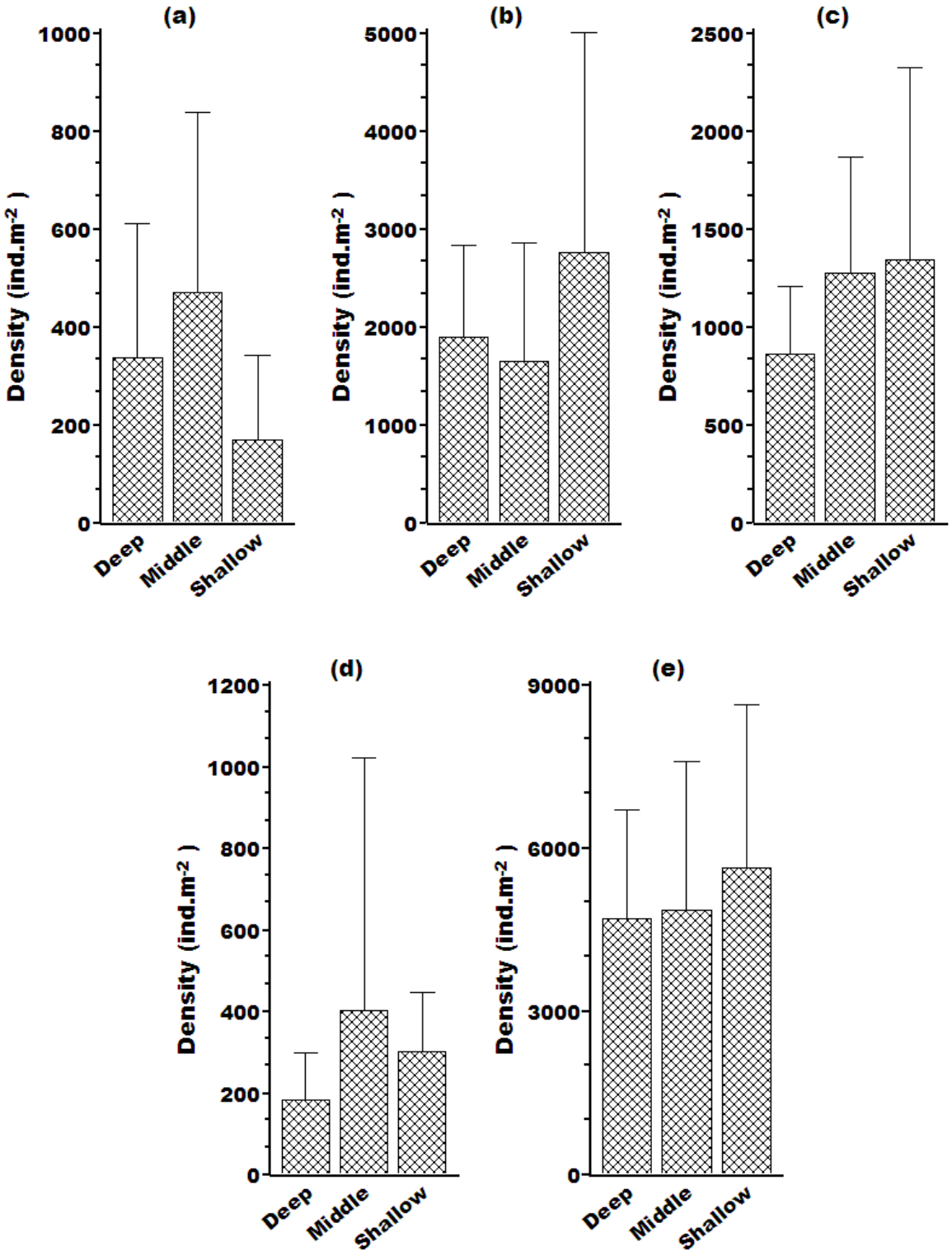

Fig. 2. Mean density (and 95% confidence limits) of chironomids at different sites within nursery ponds at Snobs Creek. (a) *Chironomus*, (b) *Polypedilum*, (c) *Procladius*, (d) Orthocladiinae spp., and (e) total chironomids.

Marked variations in the abundance of chironomid taxa were observed between months and seasons. *Chironomus* was most abundant in the first half of the season (November and December), but in the last half was low in abundance (January) or absent (February) (Figure 3a). Similarly, the densities of Orthocladiinae spp. were highest in November and December, but were considerably lower in later months (Figure 3b). In contrast, *Polypedilum* was most

abundant in later months (January and February), whereas rare or absent in early months (Figure 3c). Densities of *Procladius* were generally highest during the middle of the season (December and January) (Figure 3d). These seasonal trends were relatively consistent for the two seasons that chironomids were sampled. However, there were obvious differences in densities within months from one season to the next. *Chironomus* densities in November of the first year were considerably lower than observed in November of the second year of the study (Figure 3a). Orthocladiinae spp. were not collected in February of the second season (Figure 3b). Both *Polypedilum* and *Procladius* were more abundant in the first year than in the second year (Figure 3c and 3d). These trends were reflected in the chironomid community structure, which changed over the course of a season.

Determination of chironomid instars

Based on mandible lengths and head capsule lengths, the larvae of *Chironomus* and *Procladius* were separated into four instars, while *Polypedilum* were separated into three instars (Figure 4, Table 3). The larvae of *Chironomus* were first collected from day 9. Early instars (1st and 2nd) of *Chironomus* were in highest proportion in the first 7 days, but declined thereafter (Figure 5a). The highest proportions of 4th instar larvae occurred during the 5th week (days 24-35) (Figure 5a). Pupae of *Chironomus* were not collected in samples until day 24. Early instars of *Polypedilum* were collected from ponds as early as day 5, while pupa were first on day 11 (Figure 5b). The larvae of *Procladius* were collected from day 10, while pupae were first collected on day 26. The proportion of instars of *Procladius* collected from ponds was more or less consistent from one week to the next (Figure 5c).

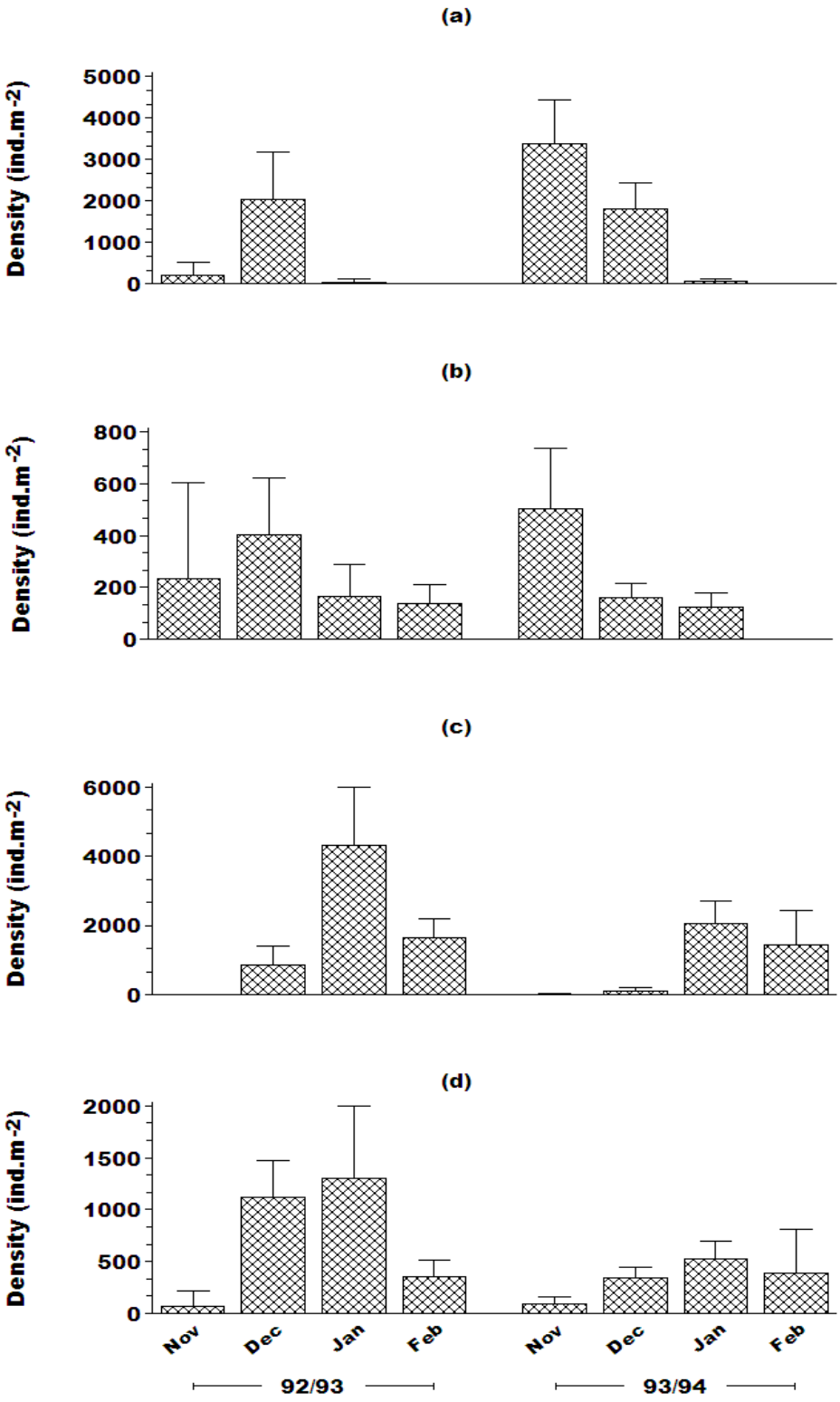

Fig. 3. Mean monthly and seasonal variations (and 95% confidence limits) in abundance of chironomids in ponds at Snobs Creek. (a) *Chironomus*, (b) Orthocladiinae spp., (c) *Polypedilum* and (d) *Procladius*.

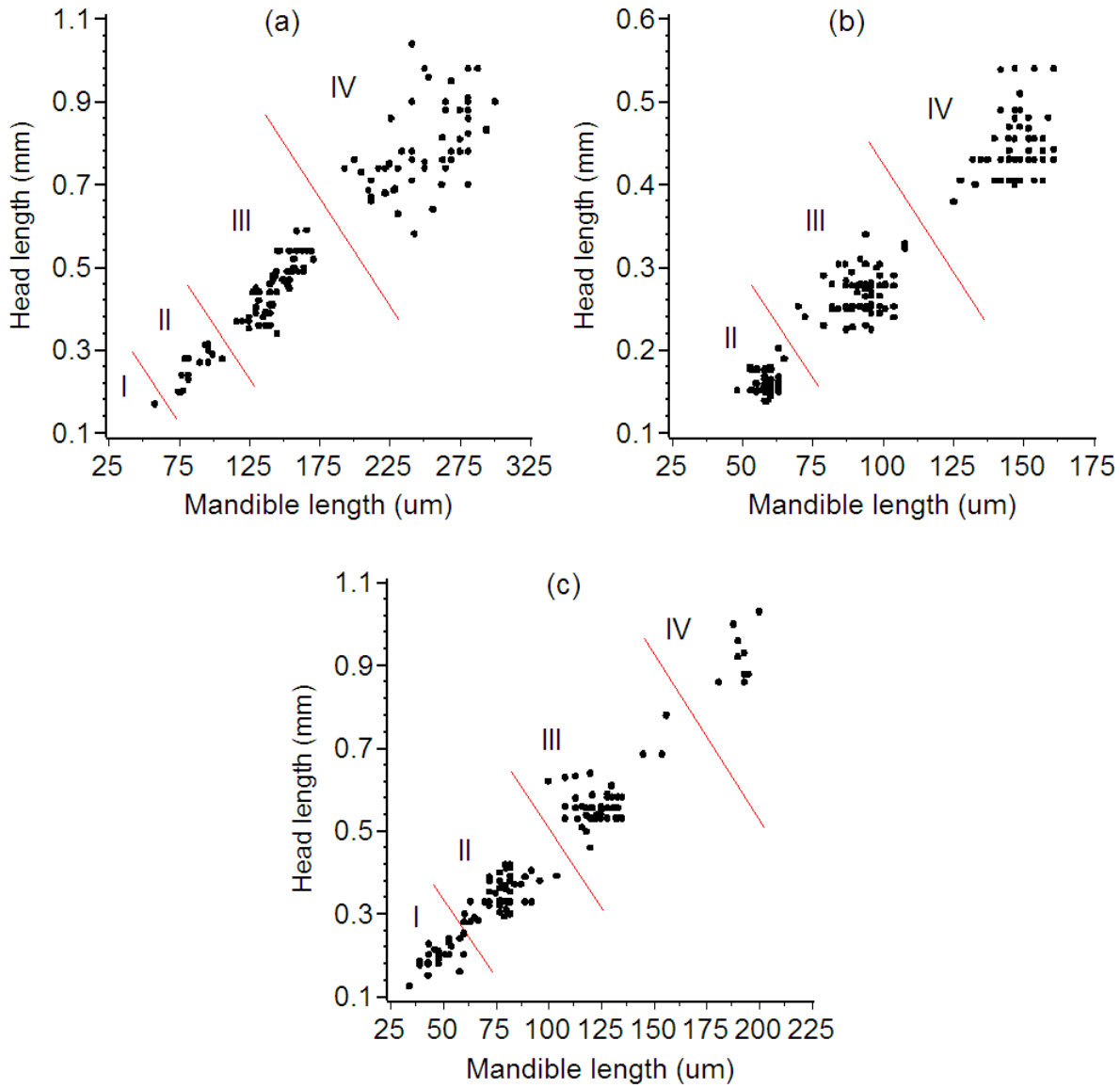

Fig. 4. Relationship between mandible length and head capsule length, and instars (indicated by Roman numerals) for (a) *Chironomus tepperi*, (b) *Polypedilum nubifer* and (c) *Procladius paludicola.*

Table 3. Body length, mandible length and head capsule length measurements for each instar of *Chironomus tepperi*, *Polypedilum nubifer* and *Procladius paludicola* collected from nursery ponds over two consecutive seasons at Snobs Creek (s.e. - standard error).

Instar	Body length (mm)		Mandible length (µm)		Head capsule length (mm)	
	No.	Range (mean ± s.e.)	No.	Range (mean ± s.e.)	No.	Range (mean ± s.e.)
***Chironomus tepperi* Skuse**						
1	5	0.9 – 2.6 (1.5 ± 0.30)	9	40 – 59 (55 ± 2.2)	2	0.10 – 0.17 (0.14 ± 0.04)
2	35	1.5 – 4.5 (2.9 ± 0.13)	115	72 – 109 (86 ± 0.8)	29	0.20 – 0.31 (0.25 ± 0.01)
3	65	1.6 – 10.0 (5.0 ± 0.20)	229	116 – 180 (144 ± 0.9)	98	0.23 – 0.59 (0.43 ± 0.01)
4	85	5.0 – 21.0 (12.0 ± 0.42)	467	193 – 355 (259 ± 1.0)	127	0.58 – 1.04 (0.76 ± 0.01)
Pupa	7	6.0 – 7.6 (6.7 ± 0.18)				
***Polypedilum nubifer* (Skuse)**						
2	108	1.1 – 2.6 (2.0 ± 0.03)	153	48 – 67 (59 ± 0.3)	99	0.14 – 0.20 (0.16 ± 0.01)
3	167	2.0 – 6.5 (3.3 ± 0.05)	278	70 – 115 (96 ± 0.4)	182	0.23 – 0.34 (0.27 ± 0.01)
4	146	3.5 – 10.0 (6.6 ± 0.13)	300	125 – 265 (153 ± 0.6)	158	0.35 – 0.54 (0.43 ± 0.01)
Pupa	3	5.0 – 6.0 (5.5 ± 0.29)				
***Procladius paludicola* Skuse**						
1	38	1.0 – 5.0 (2.0 ± 0.08)	60	34 – 65 (53 ± 0.9)	34	0.13 – 0.33 (0.22 ± 0.01)
2	71	1.4 – 4.5 (3.0 ± 0.08)	148	65 – 99 (80 ± 0.6)	65	0.25 – 0.46 (0.35 ± 0.01)
3	57	2.5 – 7.0 (4.7 ± 0.13)	185	100 – 145 (123 ± 0.7)	63	0.39 – 0.69 (0.55 ± 0.01)
4	18	6.1 – 11.0 (8.7 ± 0.36)	40	154 – 325 (193 ± 3.9)	15	0.68 – 1.03 (0.87± 0.03)
Pupa	1	5.5				

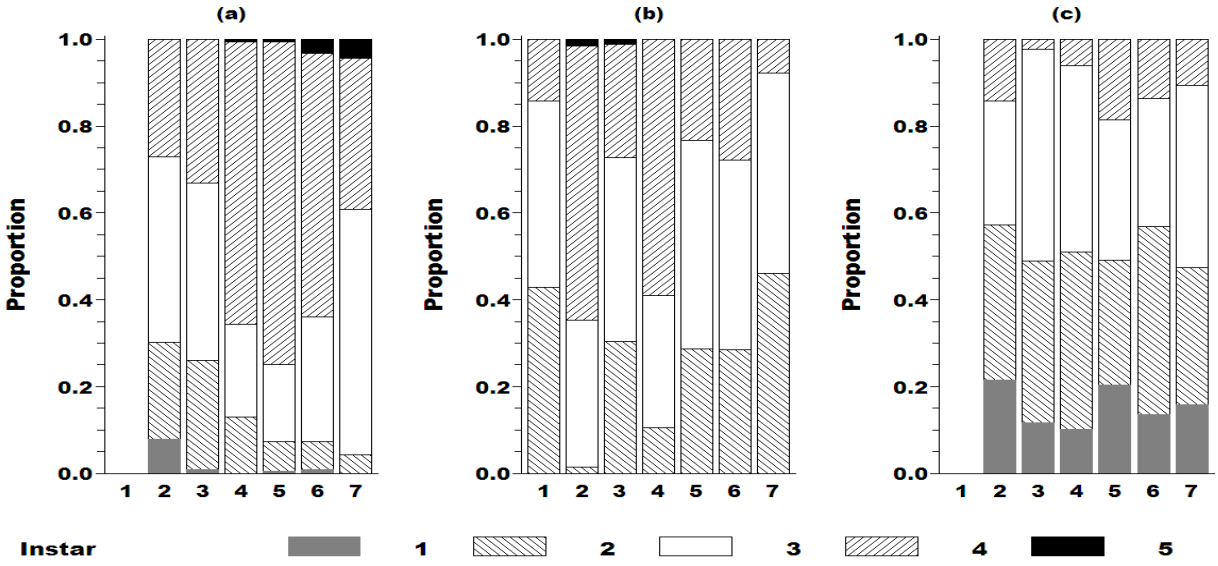

Fig. 5. Proportion of instars collected from each week from day of pond inundation. (a) *Chironomus tepperi*, (b) *Polypedilum nubifer* and (c) *Procladius paludicola*. Instar 5=pupa

Discussion

The 17 taxa observed in the ponds were considered typical of species which are common in ephemeral lentic water bodies in Australia, as similar species have been reported from swamps and floodplain wetlands in south-eastern Australia (Maher and Carpenter, 1984; Hillman and Nielsen, 1995; Suter et al. 1995). Stevens and Warren (2003) reported 18 species in rice bays in southern Australia, with *C. tepperi*, *P. paludicola* and *P. nubifer*, being the most abundant species. In comparison, these species were likely to be the most common and frequently encountered taxa in ponds at Snobs Creek.

Nearly 30% of the chironomid larvae collected during the present study were obtained by examination of fish gut contents. Use of fish as a sampling tool for chironomid larvae proved useful, as 4 taxa not collected in core samples were obtained by this method. However, differences in the occurrence and proportions of chironomid taxa between core samples from the pond and fish stomach samples should be treated with extreme caution as some chironomid species may be more susceptible to predation by fish than others. This may explain why the proportion of *K. martini*, relative to numbers of other chironomid taxa, was substantially higher in the stomach of fish (11%), than in core samples (<1%) in the present study. The larvae of *K. martini* are filter feeders, possessing long brushes on the labral margin (Cranston 1997). They may spend more time on top of the substrate feeding and thus be more visible to predacious fish than other tube dwelling or burrowing chironomid species.

The densities of chironomid larvae in ponds at Snobs Creek, which reached a mean maximum density of 27,470 ind. m^{-2}, were similar to densities observed in other water bodies. Densities of chironomids in ponds ranged from 4,700 to 23,100 ind. m^{-2} for ponds stocked with brown trout (Wahab et al. 1989; Stirling and Wahab, 1990; Wahab and Stirling, 1991), and from 22,700 to 30,600 ind. m^{-2} for carp ponds (Janecek, 1995). Higher densities have been observed in wetlands in south western New South Wales. Maher and Carpenter (1984) recorded densities of *Chironomus "alternans a"* up to 73,283 ind. m^{-2} (mean 1,931 ind. m^{-2}) and *P. nubifer* up to 33,647 ind. m^{-2} (mean 724 ind. m^{-2}), and mean total densities of chironomids to 38,509 ind. m^{-2}.

During the present study specimens of unidentified orthoclads were found in cocoons constructed from sand grains. Occurrence of cocoons in the larval stages of chironomid has been reported previously (Sæther, 1962; Danks, 1971; Grodhaus, 1976; Delettre, 1988; Tokeshi, 1995). The reasons why these orthoclads constructed cocoons in ponds at Snobs Creek are unknown, although other species construct cocoons to withstand unfavourable or stressful conditions such as temperature extremes, desiccation or drought and oxygen depletion (Sæther, 1962; Danks, 1971; Grodhaus, 1976; Delettre, 1988; Tokeshi, 1995). These orthoclads may not have been fully aquatic species as both free-living and cocooned specimens were found in the ponds as early as day 2. No attempts to identify processes and conditions that may have induced cocooning in these orthoclads were undertaken.

For the three species groups measured during the study, very few or no putative first instar larvae were collected compared to later instars. This may have been due to both the nature of first instar larvae and their size. Since, the first instar is often a planktonic/dispersal phase which lasts for a very short time (Tokeshi, 1995), it is less likely they would be collected in benthos samples. Because of their size, many first instar larvae may not have been retained in the 250 µm sieve used for sorting benthos samples. For these reasons it is likely that the abundance of first instar larvae were underestimated in the present study. In comparison to *Chironomus* and *Polypedilum*, the instars of *Procladius* were poorly differentiated. This may have been due to the presence of more than one *Procladius* species in the samples. The taxonomy of the *Procladius* genus is in disarray and attempts to resolve it have by and large been unsuccessful (Cranston, 1997). Although the instars of *Chironomus* and *Polypedilum* were well differentiated, this does not preclude the possibility that other species may have been present in the samples.

Many chironomid species show a preference for certain water depths (Danks, 1971), even in shallow waters such as in carp ponds (Janecek, 1995). In the present study, chironomid larvae were generally more abundant in the shallow section of the ponds, particularly *Polypedilum* and *Procladius*. *Chironomus*, in contrast, showed little preference to water depth. Due to the presence of oxygen retaining haemoglobin in their body (Pinder, 1986), *Chironomus* larvae are more tolerant of waters containing low oxygen concentrations, such as may occur in the deeper sections of the ponds.

The present study showed that there were substantial seasonal variations in the abundance of chironomid larvae in ponds at Snobs Creek. *Chironomus tepperi* is known to rapidly colonise newly inundated areas such as rice bays in New South Wales, in which they are numerically dominant (Stevens, 1994; Stevens, 1995), and swamps in south-western New South Wales (Maher and Carpenter, 1984). Stevens (1994) suggested that *C. tepperi* is generally univoltine and rarely recolonises rice bays after one generation. In ponds at Snobs Creek, *C. tepperi* was more abundant in the first half of the season (November and December), when the ponds were first filled, than the second half (January and February), which supports the view that this species is univoltine. In contrast, *Polypedilum*, which was rarely collected in the first half of the season, was the most common and abundant chironomid in the second half of the season. During the summer months, ponds at Snobs Creek typically have high temperatures and have high nutrient concentrations due to the addition of fertilisers (Ingram, unpublished data), which may have favoured *P. nubifer* in the second half of the season. *P. nubifer* is common and widespread in Australia and is reported to tolerate high temperatures and nutrient loadings (Cranston, 1997).

Furthermore, the decline in proportions of small instars (1st and 2nd) of *Chironomus* in ponds in later weeks suggests that recolonisation of this species was not occurring in the ponds at Snobs Creek.

Overall, the abundance of chironomid larvae in ponds at Snobs Creek increased to a maximum in the 3-5th week and declined thereafter. A similar trend was observed in

chironomid biomass in ponds stocked with juvenile walleye (Fox, 1989; Fox et al. 1989), and the decline in biomass in these ponds, which peaked in the third week, was attributed to chironomid emergence (Fox, 1989; Fox et al. 1989). This may well be the case for univoltine chironomid species, such as *C. tepperi* (Stevens, 1994), but does not account for multivoltine species, which may continually recolonise the ponds after emergence. The present study showed that the small instars (1st and 2nd) of *Polypedilum* and *Procladius* were present throughout the period when the ponds were filled with water, indicating that these species were continually recolonising the ponds. Increased predation pressure by juvenile fish may also contribute to the decline in abundance of chironomid larvae in latter weeks. Juvenile percichthyids stocked into the ponds at Snobs Creek initially fed on zooplankton, but in latter weeks, chironomid larvae became a significant part of their diet (Ingram and De Silva, 2007).

Previous studies have shown that the abundance of some chironomid species are reduced by fish predation (Hurlbert et al. 1972; Flecker, 1984; Macchiusi and Baker, 1991), while the abundance of other species are not affected or even increased (Gilinsky, 1984; Hershey, 1985; Wahab et al. 1989; Macchiusi and Baker, 1991). The abundance of *Chironomus*, *Procladius* and *Polypedilum* are likely to be influenced by fish predation in the ponds at Snobs Creek (Ingram and De Silva, 2007). Preliminary results from fish exclusion experiments indicated that the densities of *Chironomus*, *Procladius* and *Polypedilum* were higher in fish exclusion zones within the ponds, though in one experiment the density of *Polypedilum* was lower in the fish exclusion zone (Ingram, unpublished data).

The present study showed that chironomid larvae were abundant in fish ponds at Snobs Creek, and that they are an important prey item of juvenile percichthyids reared in the ponds. Increased understanding of the population dynamics of chironomids, combined with improved pond management techniques to enhance chironomid abundance, may have a positive effect on fish production. Future research may focus on developing pond management techniques that enhance chironomid larvae populations, including fertilisation regimes to improve benthic insect biomass, and use of lights to attract ovipositing midges.

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