Seasonal emergence of dragonflies (Odonata: Anisoptera) at ten ponds in Hong Kong

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Abstract

Dragonfly emergence was monitored at ten ponds in Hong Kong, using emergence traps, for periods of varying duration between February 2004 and September 2007. Three newly created ponds, five re-profiled ponds and two long-established former commercial fish ponds were included in the study.

Exuviae abundance varied considerably between ponds and years, as did the number of species recorded. There was an overall declining trend over the four year period. The causes of these variations were not determined.

Dragonfly emergence was strongly seasonal in all four years, with > 80% of total annual emergence occurring in March to May in most ponds. A winter emergence peak, dominated by *Pantala flavescens*, was recorded in ponds which had only been filled in the preceding summer.

Key words: Odonata, dragonflies, Anisoptera, Hong Kong, exuviae, emergence, seasonality.

Introduction

Hong Kong has a strongly seasonal climate, dominated by alternating warm summer and cool winter monsoons (the 'wet' and 'dry' seasons), lasting from May to September, and November to February, respectively, with transitional periods in-between (Dudgeon & Corlett, 2004). The mean annual temperature is 22.8°C, with daily temperatures averaging 28.8°C in July, but in January (the coldest month), mean daily temperatures are 15.8°C, and the thermometer can occasionally drop to below 10°C for several days at a stretch between December and March, during strong pulses of the winter monsoon. Meanwhile, 77% of annual rain falls during the summer monsoon, with just 6% during the winter dry season. Not surprisingly, this marked seasonality is reflected in the annual adult emergence patterns of various terrestrial and aquatic insect groups in Hong Kong (Dudgeon & Corlett, 2004).

In the case of Odonata, it has long been known that certain stream species in Hong Kong are univoltine (e.g., Dudgeon, 1989a; 1989b) and have a narrow late spring / early summer emergence period coinciding with the onset of the wet season and rising temperatures, followed by a relatively short flight season. These 'spring species' include damselflies (Zygoptera) in the families Megapodagrionidae, Platycnemididae and Platystictidae, one species of Calopterygidae and, amongst Anisoptera, the riverine species of Gomphidae (15 species), and members of the genus *Macromia* (Corduliidae) (Wilson, 1995; 2004). When it comes to most species found in lentic habitats such as ponds and marshes, however, the picture is less clear. Many pond species in Hong Kong can be seen on the wing from March to January of the following year (Wilson, 2004). This extended flying period led Wilson (2004) to remark that "Timing of emergence does not follow a clear pattern for most [Hong Kong] species", although he also observed that most lentic habitat species have a peak emergence in spring and continue to emerge in lesser numbers until late autumn, an observation largely corroborated in a systematic study of emergence at one pond by Reels (2009).

Between February 2004 and September 2007, I obtained data on seasonal dragonfly emergence while monitoring dragonflies at 10 different ponds situated on land owned by the Kowloon-Canton Railway Corporation – later amalgamated with the Mass Transit Railway Corporation (MTRC) – in the northwest New Territories, Hong Kong. As noted by Moore & Corbet (1990), regular exuviae counts throughout the emergence period are the best method for monitoring dragonfly (Odonata: Anisoptera) populations at a specific pond, and this can be effectively achieved by the use of dragonfly emergence supports that can increase the likelihood of finding exuviae and provide a standardized method of collection. Replicated emergence traps can permit meaningful comparisons of numbers of emerging dragonflies, per pond or per unit area (Payne, 2003), while also yielding useful information on seasonality of emergence. This paper focuses on the general seasonality of overall dragonfly emergence in the 10 study ponds, with remarks on variations between ponds and years.

Methods

Monitoring of dragonfly emergence, using standardized exuviae traps, was conducted at two newly created (in 2003) ponds near Kam Tin, and eight former commercial fish ponds or newly excavated ponds at Lok Ma Chau, on land owned by MTRC and managed by Asia Ecological Consultants (AEC), for varying lengths of time during 2004 to 2007.

The traps presented an enclosed space in which emerging dragonfly adults were trapped, and were based upon a design first used by Cook & Horn (1968). Traps were open at the bottom and at one side, with the top measuring 60cm x 60cm and the sides measuring 30cm high. They were placed at the shoreline, initially with the open side submerged so that dragonflies emerging within the traps were unable to fly out. Payne (2003) monitored dragonfly emergence from 26 small lakes in Washington, USA, using six traps per lake. In the current study, eight such traps were deployed in each study pond, with the exception of the tiny Pond 5, in which only four traps were deployed.

An exuviae trap in Pond 4

Owing to the fluctuating water levels in each pond (resulting from either evaporation, prolonged heavy rain or habitat management activities), emergence apparatus were regularly moved up or down the shore in order to maintain their position at the water margin. Hence the habitat in which each individual trap was situated could, over the course of the study period, vary from emergent macrophytes, to submerged macrophytes (in ponds where this habitat existed), to unvegetated mud. An effort was made to ensure that all available larval habitats at the pond margins at a given time were represented in the siting strategy for the emergence apparatus, with approximately equal representation for the north-, south- east- and west-facing aspects of each pond.

Exuvia of Epophthalmia elegans (Corduliidae) on emergence trap

Reels (2009) determined that mean persistence of Anisoptera exuviae in the field was 3.4 days (*n* = 45 exuviae, from five species, during the early wet season). Thus, in all ponds, exuviae on the inside and outside of each trap were collected, identified and counted every three or four days (occasionally, longer periods between collections were unavoidable).

Exuviae were subsequently identified with the aid of a dissecting microscope, using keys and illustrations provided by Zhou (1994), supplemented by various Japanese texts (Kawai, 1985; Ishida, 1996; Sugimura et al., 2001). Further confirmation of exuviae identifications was made in many cases by association with teneral adults, either when the latter had failed to completely emerge from the exuviae, or when found alongside their exuviae in emergence traps.

Table 1 gives information on the size, location and vegetational attributes of the 10 study ponds, as well as a summary of the exuviae sampling effort in each pond over the period February 2004 to November 2007.

Exuvia of Orthetrum sabina (Libellulidae) on emergence trap

Results

Emergence trends in ponds and years

Total numbers of exuviae and species emerging per pond in each year are summarised in Table 2. Exuviae abundance was generally highest in Pond 4 (apart from in 2007, when, surprisingly, zero exuviae were recorded in this pond). The highest number of species recorded emerging in any pond was 12, in Pond 3 in 2004. Annual differences in dragonfly emergence within ponds were clearly seen in Ponds 2, 4, 5 and 6, all of which were monitored for exuviae abundance from 2004 to 2007. In all four of these ponds, exuviae abundance had declined to negligible numbers by 2007. In Ponds 2, 5 and 6, this decline was progressive over the study period, whereas in Pond 4 there was a significant recovery in 2006 (followed by zero exuviae in 2007).

Table 1. The study ponds

Pond	Site	Position	Area (ha)	Trapping history	Physical attributes
1	Kam Tin	22°26’40.8”N, 114°03’19.2”E	1.4	Eight traps set February 2004; removed March 2005.	A large, newly-created (2003) pond without floating or submerged macrophytes. Emergent vegetation comprising sedges, rushes, grass and reed.
2	Kam Tin	22°26’28.7”N, 114°03’31.7”E	0.4	Eight traps set from March 2004 to September 2005; Mar-Sep 2006; Mar-Nov 2007.	A small, newly-created (2003) pond with floating and emergent macrophytes. Briefly drained late May 2004. Water level fluctuated widely over the four years.
3	Lok Ma Chau	22°30’35.7”N, 114°03’40.7”E	1.2	Eight traps set from Feb-Oct 2004. Traps completely inundated in October 2004.	A large, shallow (max. depth ca 1m) former fish pond, with extensive growth of emergent grass, and reeds at the southern end.
4	Lok Ma Chau	22°30’35.9”N, 114°03’46.2”E	1.2	Eight traps set February 2004 to September 2005; Mar-Sep 2006; Mar-Sep 2007. Temporarily removed 27 May to 19 July 2004 due to partial draining activities; traps completely submerged throughout October 2004.	A large, long-established, relatively deep fish pond (max. depth >1.5m), lacking floating or submerged macrophytes. Emergent vegetation along the pond margin comprised entirely of *Panicum* grass. Open water > 99% of the pond area.
5	Lok Ma Chau	22°30’33.5”N, 114°03’46.7”E	<0.1	Eight traps set November 2004 to January 2005; reduced to four traps Feb-Sep 2005; Mar-Sep 2006; Mar-Sep 2007.	A very small, shallow, newly excavated pond, planted with sedge and reed and with emergent grass around the margin.
6	Lok Ma Chau	22°30’39.4”N, 114°03’52.7”E	0.7	Eight traps set from November 2004 to September 2005; Mar-Sep 2006; Mar-Sep 2007.	A shallow, medium-sized marshy pond established late summer 2004 with rooted submerged macro-phytes, sedge and reed.
7	Lok Ma Chau	22°30’47.1”N, 114°03’52.5”E	0.3	Eight traps set Mar-Sep 2006; Mar-Sep 2007.	A small, shallow marshy pond, established by late 2005, with rooted submerged macrophytes and sedge.
8	Lok Ma Chau	22°30’48.0”N, 114°03’58.0”E	0.6	Eight traps set September 2006 to September 2007.	A medium-sized pond, newly planted with lotus and with short emergent grass at the margin.
9	Lok Ma Chau	22°30’45.8”N, 114°03’58.8”E	0.6	Eight traps set Mar-Sep 2007.	A medium-sized pond, newly planted with lotus and with short emergent grass at the margin, established by late 2006.
10	Lok Ma Chau	22°30’48.4”N, 114°04’02.0”E	0.4	Eight traps set Mar-Sep 2007.	A small pond, newly planted with rooted submerged macrophytes and with short emergent grass at the margin, established by late 2006.

Pond 1, 2004-2005

Exuviae abundance was extremely low in this pond (Figure 1), with just eight exuviae of a single species, *Ictinogomphus pertinax*, recorded on the traps. Four of these were collected in May 2004, two in June and two in July. No exuviae were recorded from August 2004 to March 2005, after which the study was terminated in this pond due to a water buffalo destroying all the apparatus.

Pond 2, 2004-2007

Eight species of Anisoptera were recorded as exuviae in Pond 2 in 2004, and 204 exuviae were collected. 33% of overall dragonfly emergence (Mar-Dec) was in April, 37% in May and 18% in June. Exuviae were recorded in considerably lower numbers in March, July, August, November and December (Fig. 1). In Jan-Sep 2005, 143 exuviae (of totally six species) were collected, 43% of which occurred in April, and 50% in May.

Only single exuviae were found in June and July, and none at all Aug-Sep (Fig. 2). In Mar-Sep 2006, 111 exuviae (of six species) were collected. 41% were collected in March, 56% in April, and none after July (Fig. 3). In Mar-Nov 2007, only a single exuviae was collected, in April.

Table 2. Annual emergence per pond

Pond	Exuviae abundance (species)			
	2004	2005	2006	2007
1	8 (1)	-	-	-
2	204 (8)	142 (6)	111 (6)	1 (1)
3	125 (12)	-	-	-
4	504 (6)	133 (8)	402 (8)	0 (0)
5	113 (2)	53 (9)	12 (6)	2 (1)
6	104 (1)	201 (9)	9 (6)	4 (4)
7	-	-	17 (3)	10 (7)
8	-	-	180 (4)	264 (8)
9	-	-	-	534 (9)
10	-	-	-	30 (7)

Pond 1

Pond 2

Pond 3, 2004

Totally 125 exuviae (from 12 species) were collected in 2004. 18% were in March, 50% in April and 19% in May. No exuviae were recorded in February or in Sep-Oct (although rising water levels had submerged the traps by October) (Fig. 1).

Pond 4, 2004-2007

Totally 504 exuviae (from six species) were recorded in 2004, with 34% of overall dragonfly emergence in March, 45% in April and 18% in May. No exuviae were recorded in February, June (when monitoring was suspended), and Sep-Oct (when traps were inundated). Totals of three and two exuviae, respectively, were recorded in November and December (Fig. 1). In Jan-Sep 2005, 133 exuviae were collected (eight species). 50% of all emergence occurred in April, and 32% in May. No exuviae were recorded Jan-Feb, and only two in September (Fig. 2). In Mar-Sep 2006, 402 exuviae (from eight species) were collected. Exuviae were collected in every month, but Apr-May was the peak emergence period, with 53% in April and 21% in May. 10% of overall recorded emergence occurred in March (Fig. 3). In Mar-Sep 2007, no exuviae were recorded.

Pond 4

Pond 5, 2004-2007

A relatively large number of exuviae (113) were recorded in Nov-Dec 2004 (Fig. 1), dominated by the libellulid *Pantala flavescens* (111 exuviae) – a pioneer species, able to fly immense distances with seasonal rains, and known to have a very rapid larval development (Corbet, 1999; 219; Suhling et al., 2009) which would allow maturation of larvae from eggs deposited in the pond in mid-summer 2004, when the pond was first established. In Jan-Sep 2005, 53 exuviae (from nine species) were collected. 28% of all emergence was in January (a continuation of the *P. flavescens* emergence of Nov-Dec 2004). 11% of emergence was in March, 36% in April, and 21% in May. No exuviae were collected in February, and only two in Jun-Sep (Fig. 2). In Mar-Sep 2006, emergence was much lower (12 exuviae from six species). 50% of exuviae were recorded in April, none in March, and the remaining 50% spread

Pond 5

across May-Sep (Fig. 3). In Mar-Sep 2007, only two exuviae were recorded, in March.

Pond 6, 2004-2007

As in Pond 5, a relatively large number of *P. flavescens* exuviae (104) were recorded in Nov-Dec 2004 (Fig. 1), representing the first colonisers of the pond. Subsequently, in Jan-Sep 2005, 201 exuviae (from nine species) were recorded. 11% of these were in March, 65% in April and 19% in May. No exuviae were recorded after August (Fig. 2). In Mar-Sep 2006, only 9 exuviae were collected (six species). Three of these (33%) were in April; the remainder were scattered in March and Jun-Sep (Fig. 3). In Mar-Sep 2007, only four exuviae were collected (four species); two in March and two in April.

Pond 6

Pond 7, 2006-2007

Totally 17 exuviae, from three species, were collected Mar-Sep 2006. Eight exuviae (47%) were in April; five (29%) in May. No exuviae were recorded after June (Fig. 3). In Mar-Sep 2007, 10 exuviae (from seven species) were collected, all in the period Mar-May (Fig. 4).

Pond 8, 2006-2007

In Sep-Dec 2006, 180 exuviae (from four species) were collected; 29% in September, 32% in October, 35% in November and 4% in December (Fig. 3). This late emergence followed summer filling of the pond, and more than half the exuviae collected (103) were of *P. flavescens*. In Jan-Sep 2007, 264 exuviae were collected (eight species). 38% were in March, 40% in April and 13% in May. No exuviae were recorded in January or Aug-Sep (Fig. 4).

Pond 9, 2007

Totally 534 exuviae were collected (nine species). 31% were in March, 49% in April and 12% in May. No exuviae were recorded in Aug-Sep (Fig. 4).

Pond 10, 2007

Totally 30 exuviae were collected (seven species). 63% were in April and 27% in May. No exuviae were recorded in Aug-Sep (Fig. 4).

Figure 1. Dragonfly exuviae abundance, 2004

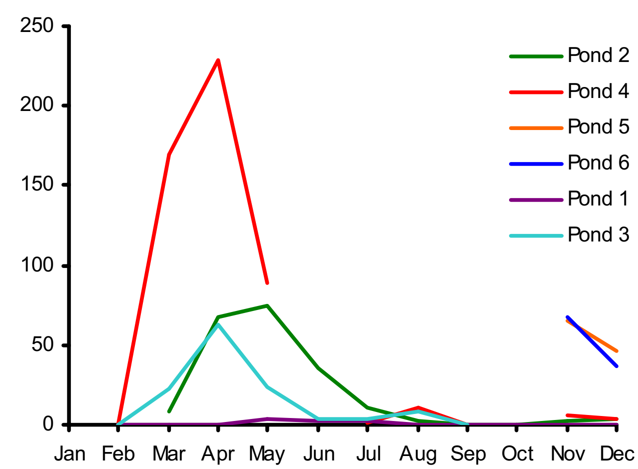


Figure 2. Dragonfly exuviae abundance, 2005

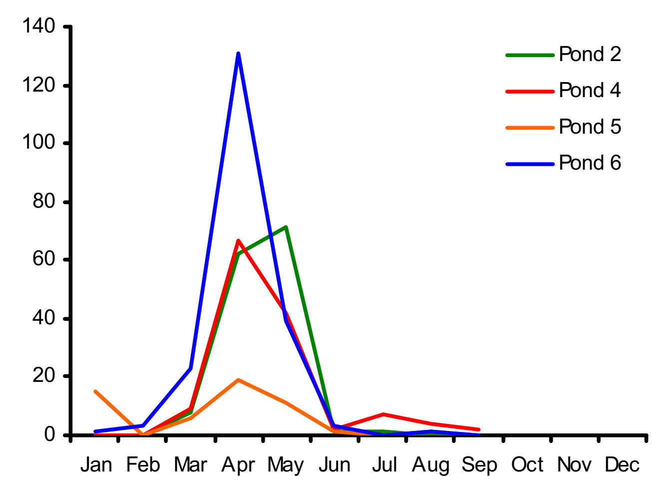


Figure 3. Dragonfly exuviae abundance, 2006

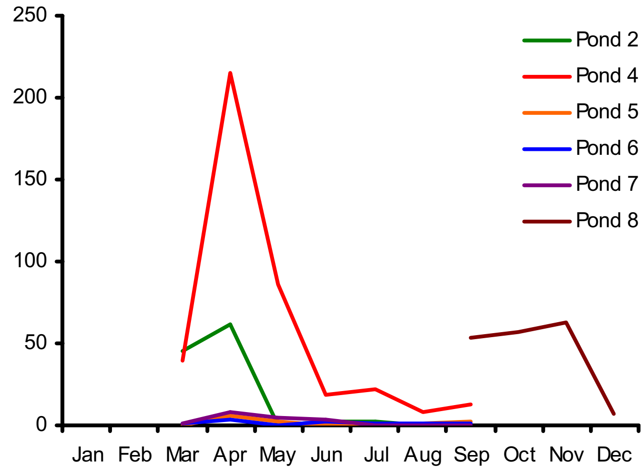
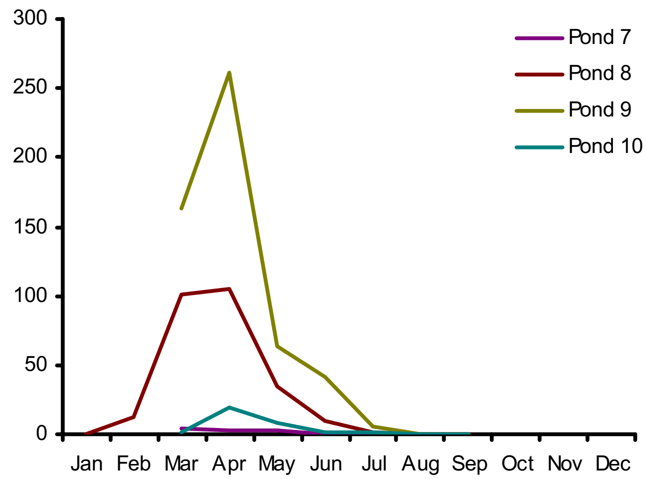


Figure 4. Dragonfly exuviae abundance, 2007



Species

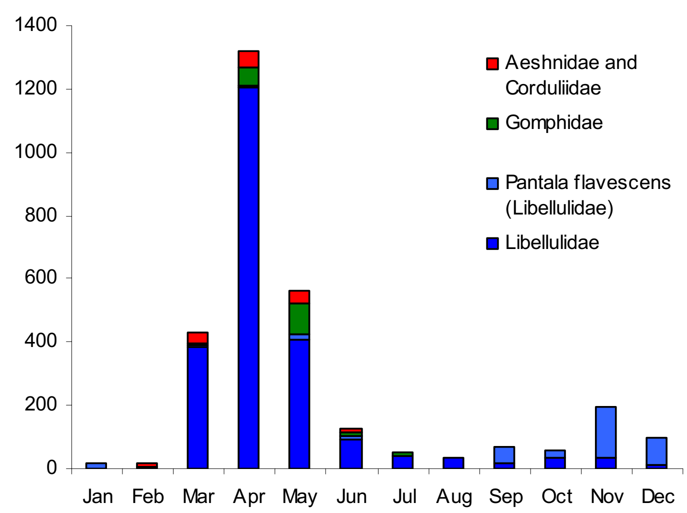
A total of 16 species of Anisoptera was recorded emerging on exuviae traps, across all ponds, over the four years. These included three species of Aeshnidae, two gomphids, one corduliid and 10 species of Libellulidae. Libellulids accounted for > 90% of exuviae abundance in 2004, 2006 and 2007, but in 2005 large anisopterans in the families Aeshnidae, Gomphidae and Corduliidae comprised more than a third of all exuviae collected (Table 3). Of the 16 species, 11 were recorded in all four years, one in three years, one in two years, and three in one year only. In 2004-2006, *Brachythemis contaminata* was by far the most commonly encountered species (particularly abundant in Pond 4), while *Orthetrum sabina* and *Diplacodes trivialis* comprised more than 80% of all exuviae collected in 2007. *O. sabina* numbers were relatively stable, as a proportion of all exuviae, across the four years, whereas the annual proportional representation of the majority of species fluctuated widely, usually over an order of magnitude.

General pattern of emergence

Dragonfly emergence, in terms of total number of exuviae of all species, was strongly seasonal in the majority of ponds, with a March-May peak (usually exceeding 80% of recorded emergence) seen in all four years. Typically, maximum monthly emergence was in April (sometimes exceeding 50% of total recorded annual emergence); less frequently it was in May or March. The data from all ten ponds over all four years is amalgamated in Fig. 5 to give a broad annual emergence pattern.

In general, the spring peak was followed by a rapid decline in emergence over the summer months, dwindling to zero or negligible emergence by September (Figs. 1-4). In three newly filled ponds (Ponds 5 and 6 in 2004, and Pond 8 in 2006), however, a significant winter emergence was observed (Figs. 1 and 3). It is noteworthy that in two of these cases (Pond 5 in Nov 2004 to Jan 2005, and Pond 6 in Nov-Dec 2004), the migratory libellulid *Pantala flavescens* comprised 98% and 100%, respectively, of exuviae collected, while in Pond 8 in Sep-Dec 2006 it comprised 57%. Libellulids in general were numerically dominant, while the proportion of exuviae of large-bodied anisopterans in the families Aeshnidae, Gomphidae and Corduliidae reached 26-28% in May, June and July. Over 50% of all exuviae collected in February were of the aeshnid *Anax parthenope*, emerging early in 2007 in Pond 21.

Figure 5. Exuviae abundance by family, summed for all years and ponds



Discussion

The eight exuviae traps in each pond (four in Pond 5) could only sample a very small portion of the margin and, in most cases, were not deployed during the period October to February, meaning that there is limited hard data for emergence over the cool dry season. Nevertheless the standardized approach makes it possible to discern broad trends in emergence across the various study ponds. Moreover, it seemed reasonable to assume from my own extensive field observations and from

Table 3. Species emerging on exuviae traps: % of annual emergence, 2004-2007

Species	2004	2005	2006	2007
Aeshnidae				
Anaciaeschna jaspidea (Burmeister)	0.2			
Anax guttatus (Burmeister)	0.2	1.5	0.5	2
Anax parthenope (Brauer)	1.5	7.4	0.4	3.7
Gomphidae				
Ictinogomphus pertinax (Hagen in Selys)	2.8	9.5	1	0.6
Sinictinogomphus clavatus (Fabricius)		14.6	1.9	
Corduliidae				
Epophthalmia elegans (Brauer)	0.8	1.1	0.1	0.5
Libellulidae				
Brachydiplax chalybea Ris	3.6	0.2	0.1	0.2
Brachythemis contaminata (Fabricius)	50.8	24.7	48.2	2.7
Crocothemis servilia (Drury)	2.7	15.3	1.9	0.6
Diplacodes trivialis (Rambur)	0.2	1.1	2.3	39.1
Orthetrum sabina (Drury)	13.5	17.8	28.9	41.5
Pantala flavescens (Fabricius)	21.1	4	14.4	3.6
Rhyothemis variegata (Drury)	0.2	0.2	0.3	0.9
Tholymis tillarga (Fabricius)	1.1			
Tramea virginia (Rambur)	0.8	2.6		4.6
Zyxomma petiolatum Rambur	0.5			
Total (actual number)	100 (1058)	100 (529)	100 (731)	100 (845)
Number of species	15	13	12	12

remarks made by Wilson (1995; 2004) that dragonfly emergence is typically negligible over the cool dry season (except under special circumstances; see below). As further corroboration of this, Reels (2009) made a comprehensive study of dragonfly emergence at one small Hong Kong pond over 17 consecutive months, and recorded no exuviae whatsoever between 8 September 2004 and 28 February 2005.

Different ponds, different years

As noted by Payne (2003), dragonfly populations in ponds are known to be very dynamic: a single pond may produce large numbers of dragonflies, but emergence is extremely variable among ponds and years. Overall exuviae abundance varied considerably between ponds in the current study, seemingly irrespective of pond size and vegetation profile. For example, the very large, open water Pond 1 had a variety of emergent vegetation, including stands of rushes and reeds as well as sedge and grass, yet only eight exuviae (of a single species) were collected during uninterrupted trapping over the period February 2004 to March 2005. In the same period, the similar-sized Pond 4, with marginal emergent vegetation entirely comprising *Panicum* grass, yielded more than 500 exuviae (of six species, albeit dominated by the libellulid *Brachythemis contaminata*). In 2007, Pond 9 yielded more than double the number of exuviae of the adjacent, similar-sized and similarly vegetated Pond 8. Certain species were apparently limited to only a very few ponds; for example *Epophthalmia elegans* only in Ponds 2, 4, 6 and 10, and *Sinictinogomphus clavatus* in Ponds 2 and 4. Three species (*Anaciaeschna jaspidea*, *Tholymis tillarga* and *Zyxomma petiolatum*) occurred in Pond 3 and nowhere else. These differences are difficult to explain with the available data.

With regard to the overall progressive decline in abundance of exuviae, year on year, this may have been due to an increasing predation impact from the growth and proliferation of predatory fish, as previously suggested for another small pond in Kam Tin (Reels, 2009). However there are a number of other variables at work (for example, a rapid proliferation of exotic *Pomacea* apple snails in Pond 2 over the same period) and it was unfortunately beyond the scope of this study to rigorously identify the causes, and eliminate the confounding variables, of these annual variations.

Clear seasonality

In spite of the large inter-year and inter-pond variations in exuviae abundance and species composition, there was a consistent seasonal trend in overall dragonfly emergence. As noted above, the period March to May is a transitional period in Hong Kong between the end of the cool, dry northeast monsoon and onset of the warm, wet southwest monsoon. The period sees steadily rising water temperature, which presumably acts as an important trigger for final instar anisopteran larvae to commence metamorphosis, leave the water and emerge as adults (other 'triggers' might include rising air temperature, humidity and increasing day length) (Corbet, 1999, 234-246; Dudgeon &

Corlett, 2004, Ch. 4). A migratory species such as *Pantala flavescens* (swarms of which move over large distances within the intertropical convergence zone) can, however, buck this general emergence trend, and winter emergence of this species is not unexpected, given the arrival of so many late summer *Pantala* on autumn typhoons around late September to October from the south (maybe from the Philippines; Keith Wilson, pers. comm.). The rapid larval development of this opportunistic coloniser, combined with the initial lack of large predatory fish in the new ponds, presumably facilitated this species' late autumn / winter emergence mass emergences in Ponds 5, 6 and 8.

Given that the adult flying season of lentic habitat anisopterans in Hong Kong commonly extends to December and beyond (Wilson, 1995, 2004; Cheung, 2008; Reels, unpublished observations), it appears likely that such dragonflies are capable of surviving as adults for several months. The very consistent Mar-May emergence period (containing sometimes in excess of 90% of a year's emergence), witnessed at a variety of ponds over up to four consecutive years, is nevertheless rather surprising for a 'tropical' location, and is perhaps more typical of emergence patterns of 'spring' species in temperate latitudes (Corbet, 1999; 244-248). Hong Kong's cool winters and latitude at 22ºN, however, mean that the climate is 'subtropical', rather than tropical. As summarized by Corbet (1999): "In subtropical latitudes, a generation of a tropical [odonate] species can last two and one-half times as long during the colder season, thus foreshadowing the overwintering patterns found in temperate-centred dragonflies".

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