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A ranking of key dragonfly sites in Hong Kong using a species conservation value assessment metric

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Abstract

Dragonflies were surveyed at 33 sites across the territory of Hong Kong Special Administrative Region over the period 2016-2017. Surveys included identification of larvae, exuviae and adults, and involved 92 separate site visits. The chosen sites covered the whole spectrum of dragonfly habitats in Hong Kong, with the exception of actively managed fish ponds and reservoirs. Twenty-two of the study locations had been identified as "key dragonfly sites" by Wilson (1997a); eight of these are found to no longer merit such status. Two of the "key dragonfly sites" are here retained and expanded to include adjacent dragonfly-rich areas, and four new key dragonfly sites are proposed. Sites are evaluated by species richness, number of species of conservation importance (Reels 2019), and by means of a species conservation value metric (Reels 2019) applied to the entire dragonfly species assemblage present at each site. By all such measures, Sha Lo Tung / Hok Tau is determined to be Hong Kong's premier dragonfly site.

Key words: Hong Kong, Odonata, key dragonfly sites, conservation importance, species assessment metric

Introduction

The Hong Kong Special Administrative Region is an area of rugged hills and islands lying just south of the Tropic of Cancer on the coast of southern China. It occupies a land area of 1,100 km² and has a subtropical monsoon climate. As noted by Reels (2019), to which the present study is a companion paper, the Hong Kong Odonata fauna currently stands at around 122 species, rising to 128 when historical species records for which there are no recent confirmations are included. All lentic and lotic freshwater habitats in Hong Kong, from temporary rain pools to big reservoirs and from tiny forest seepages to large lowland streams, are utilised as breeding and larval habitat by different odonate species. Two Hong Kong species, *Mortonagrion hirosei* Asahina, 1972 and *Orthetrum poecilops* Ris, 1919, are able to breed in brackish coastal mangroves and reedbeds, and are essentially restricted to these habitats (Reels, 2019).

Since the early 1990s, there has been continuous and growing study of the Hong Kong odonate fauna. Two general trends over the ensuing quarter-century can be surmised; both are related to habitat change. The drastic reduction in lowland wetlands such as active or abandoned fish ponds, rice paddies and wet vegetable fields that has occurred over the last few decades, through rapid changes in human land use, must inevitably have impacted negatively on the many pond and marsh species

which breed in these habitats. Reels (2019) identified three such species – *Paracercion calamorum* (Fraser, 1919), *Nannophya pygmaea* Rambur, 1842 and *Palpopleura sexmaculata* (Fabricius, 1778) – as having declined in Hong Kong in recent decades. Similarly, lowland riverine species will have been badly affected by the unfortunate practice of channelising streams and rivers across the SAR and the stripping out of riparian vegetation along river banks. The extent of these impacts is not possible to quantify, but it is intuitively obvious that the more habitat that is lost, the worse the impacts will be. The second trend is of an ongoing recolonisation of Hong Kong by forest-associated dragonflies as woodlands in the territory continue to grow back and mature. Wilson (2014) argued that more than 20 large, strong-flying forest anisopterans first recorded in the SAR after 1990 were genuine new arrivals (as opposed to having been historically overlooked), recolonising from forested areas of Guangdong due to recent forest recovery in Hong Kong after a thousand years of severe anthropogenic deforestation. This trend is ongoing (Reels 2019).

Habitat loss is the major threat to Hong Kong dragonflies. As noted above, this is a particular problem for species of open lowland wetlands. Ponds and marshes in Hong Kong tend to occur outside of Country Parks, or within Country Park Enclaves, making them particularly vulnerable. Actively farmed fish ponds are still quite abundant, particularly in the northwest New Territories, but are of far less value as dragonfly habitat than disused ones in which rooted, submerged macrophytes and floating vegetation are established. Such ponds, which can support very diverse dragonfly assemblages, are very rare in Hong Kong. Similarly, lowland rivers with natural substrates and riparian zones are increasingly scarce as the Drainage Services Department continues its practice of channelising all natural waterways outside of the protected areas system, leaving them habitable by only the most tolerant and ubiquitous species. The majority of forested hill streams, trickles and seeps, however, are located within Country Parks and in consequence enjoy a degree of protection.

In 1997, Keith Wilson published an important paper on the status and distribution of Hong Kong dragonflies in the Memoirs of the Hong Kong Natural History Society (Wilson 1997a). This paper summarised the key findings of Wilson's studies of the Hong Kong odonate fauna over the period 1991-1997, identifying 23 "key dragonfly sites" (out of more than 90 surveyed) supporting "endemic, internationally rare species or rich dragonfly assemblages". The key sites represented the entire range of dragonfly habitats existing within the territory, from mountain seeps to coastal marshes.

In April-July 2016 and May-June 2017, the author was employed by the School of Biological Sciences, The University of Hong Kong, to undertake surveys of dragonflies, focusing particularly on reassessing the key sites identified by Wilson (1997a) and on identifying other important dragonfly sites. The study also permitted a reassessment of the local status and distribution of Hong Kong dragonfly species and identification of species of conservation importance, as described in Reels (2019), the companion paper to this study. It should be noted that the check list of Hong Kong species given in Reels (2019) listed Stylurus kreyenbergi Ris, 1928. This was an oversight: that name was established as a junior synonym of *Stylurus annulatus* (Djakonov, 1926) by Wilson (2019).

Methods

Dragonfly larvae, exuviae and adults were surveyed, in a total of 92 field surveys (at 33 sites distributed across the territory of Hong Kong), as described by Reels (2018). Larval sampling was particularly useful for detecting the presence of gomphids, many species of which can be highly elusive as adults. Each of the 23 key dragonfly sites named by Wilson (1997) was visited at least once (one site, Kau Sai Chau Pond, was not found by the author but was relocated by Keith Wilson in a visit in June 2018). In addition, a further 11 wetland sites were surveyed on at least one occasion to provide a comparison with the key dragonfly sites and to determine whether additional key dragonfly sites should be nominated. Sites were assessed based on species-richness and by use of a species conservation value metric. The data from surveys conducted (totally 92 surveys conducted April to July 2016 and May to June 2017) were occasionally augmented with species records made by private individuals during the survey period (taken as the calendar years 2016 and 2017), where those particular species were not observed.

Key dragonfly sites (after Wilson 1997a)

One of the key dragonfly sites identified by Wilson (1997a), Kau Sai Pond, could not be found by the author during the present study but was relocated in a badly deteriorated state in 2018 by Keith Wilson: "This once nice little site... is now becoming choked up... I fear the site has been excessively compromised" (Wilson pers. comm. June 2018). The remaining 22 sites and the 11 new sites are described below. The locations of the sites are indicated in Figure 1.

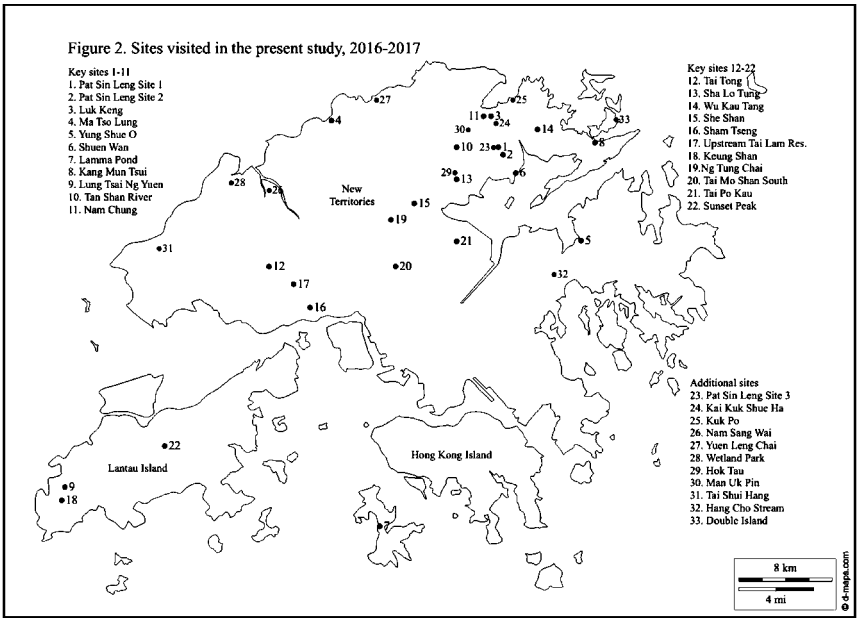


Figure 1: Map of locations studied.

1. Pat Sin Leng Site 1 (N 22º29.599', E 114º13.514'. 220m asl. Surveyed 19-04-16, 16-05-16, 08-05-17)

This small (ca 1 ha) site is an abandoned rice paddyfield at about 220m asl in Pat Sin Leng Country Park. It is formed in a natural depression and Wilson (1997a) speculated that it may have been a bog or marsh before its conversion to agricultural use. The site was of particular significance through being the only known breeding site for *Lestes nodalis* Selys, 1891 in Hong Kong, a species otherwise not known in China from east of Yunnan province at that time. On this basis, Wilson (1997a) strongly recommended the site be designated a Site of Special Scientific Interest (SSSI). The marsh is bissected by a raised concrete path which permits seepage of water from the northern to the southern parts.

Unfortunately, although the *L. nodalis* population was still evident in 2006 (Reels pers. obs. June 2006) the site has become drier and shrubbier in the ensuing decade, through a process of natural succession, and no individuals of *L. nodalis* were encountered at the site. An impoverished fauna of just eight species was recorded over the course of three field visits (Appendix 1.1).

2. Pat Sin Leng Site 2 (N 22º30.155', E 114º13.439'. 245m asl. Surveyed 19-04-16, 16-05-16, 08-05-17)

This very small site (ca 0.25 ha) is another abandoned paddyfield, located a short distance to the northeast of Pat Sin Leng Site 1 at about 250m asl. In the 1990s the site supported a thriving population of the tiny dragonfly, *Nannophya pygmaea* Rambur, 1842 then known from only two other breeding sites in Hong Kong (Wilson 1997a). The site's local importance was raised further by the discovery, in 2000, of a small population of the diminutive damselfly *Aciagrion approximans* (Selys, 1876) (Wilson & Reels pers. obs. May 2000), not previously known from Hong Kong (and identified as a species of local conservation interest by Reels 2019). Two specimens were seen in May 2000 in a narrow trickle beside the footpath running along the edge of the marsh. This trickle still exists, in spite of the rest of the marsh having now become densely overgrown with the fern *Dicranopteris*, with little or no standing water. Again, this deterioration is a consequence of natural vegetation succession. In this case it has resulted in the complete loss of a wetland that formerly supported many dragonflies.

No *N. pygmaea* or *A. approximans* were found at the site over the course of three site visits. Totally only five dragonfly species were recorded (Appendix 1.1).

3. Luk Keng marsh (N 22º31.088', E 114º13.098'. 2m asl. Surveyed 17-04-16, 21-04-16, 23-05-16, 15-06-17)

This very large marsh in the northeast New Territories was identified by Wilson (1997a) as a key dragonfly site primarily on the presence of the tiny salt-tolerant damselfly *Mortonagrion hirosei*, which at the time was classified as Endangered on the IUCN Red List and outside of Japan was known from only two other sites in the territory. Wilson (1997a) also highlighted the presence of two small libellulids, *Nannophyopsis clara* (Needham, 1930) (patchily distributed in China) and *Rhyothemis triangularis* Kirby, 1889 (unrecorded elsewhere in China), as supporting argument for his recommendation that the site be designated a Site of Special Scientific Interest (SSSI).

The site was visited on four dates. Survey efforts focused primarily on reconfirming the presence of *M. hirosei* in the more saline reed- and mangrove-dominated part of the marsh and on surveying the feeder streams at the back of the marsh for *N. clara* and *R. triangularis* in addition to covering the main freshwater marsh body. All three species were reconfirmed at the site. A total of 35 species was recorded (Appendix 1.1). Two species of conservation interest (*Macromidia ellenae* Wilson, 1996 and *Orthetrum poecilops*) were recorded (the former by Bergman Ng in a private visit; the latter in a mangrove patch at the northwest of the marsh), as was *Aethriamanta brevipennis* (Rambur, 1842), a small red libellulid widely distributed in Asia but not recorded in Hong Kong before 2008 (Tam et al. 2008). Conversely, the locally rare libellulid *Diplacodes nebulosa* (Fabricius, 1793) was recorded by Wilson in the 1990s but not in the present study.

4. Ma Tso Lung (N 22º31.156', E 114º05.148'. 2m asl. Surveyed 15-06-16, 28-06-16, 22-05-17)

This is an extensive mosaic of freshwater marsh, fish ponds, abandoned ponds and abandoned paddies lying in the former Frontier Closed Area to the east of Lok Ma Chau. Wilson (1997a) stated that the area supported "perhaps the best freshwater wetland fauna in Hong Kong" and considered the site to be of very high conservation interest, worthy of SSSI designation. In particular, the site supported large populations of two libellulids, *Rhodothemis rufa* (Rambur, 1842) and *Urothemis signata* (Rambur, 1842), that at the time were rare in Hong Kong and unrecorded elsewhere in the northwest New Territories.

The area was visited on three dates and although far too extensive to survey thoroughly was found to support a large number (33) of pond/marsh species, including robust populations of both *R. rufa* and *U. signata* in addition to ten species not recorded by Wilson in the 1990s, including *Rhyothemis triangularis* and the recent arrival *Aethriamanta brevipennis* (Appendix 1.1). The value of this vast wetland as dragonfly habitat has apparently increased in the 20 years since Wilson (1997a).

5. Yung Shue O (N 22º25.364', E 114º17.251'. 5m asl. Surveyed 18-05-16, 01-06-16, 02-06-17)

Wilson (1997a) identified this freshwater marsh as a key dragonfly site on the basis of its large breeding colony of *Nannophya pygmaea*, a species then known from only three sites in Hong Kong. The species could not be found in the present study, over the course of three site visits.

Some 23 species were recorded at the site (Appendix 1.1). It is notable that one species of conservation interest, the mangrove-associated *Orthetrum poecilops*, was recorded in the present study (in coastal mangrove close to the freshwater marsh) but not in the 1990s.

6. Shuen Wan (N 22º28.021', E 114º12.206'. 0m asl. Surveyed 18-05-16, 21-06-16, 25-05-17)

This coastal freshwater/saltwater wetland mosaic was designated a key dragonfly site owing to the presence of *Onychargia atrocyana* Selys, 1865 (a damselfly with a restricted distribution in Hong Kong) and *Orthetrum poecilops* (Wilson 1997a). Both species are still considered to be of conservation interest (Reels 2019).

The site was visited on three dates and the continued presence of the two species was confirmed. Twenty species were recorded in total (Appendix 1.1).

7. Lamma Pond (N 22º12.891', E 114º07.399'. 60m asl. Surveyed 08-06-16)

Wilson (1997a) reported two locally rare libellulids, *Diplacodes nebulosa* and *Rhyothemis triangularis*, from this tiny (ca 0.02 ha) pond on Lamma Island. *D. nebulosa* was otherwise only known in Hong Kong from a record made by Wilson in Luk Keng in 1994 (Wilson 1997a) and a single historical record by Lai (1971), while *R. triangularis* was at that time known from only four sites in the territory (Wilson 1997a).

I briefly visited this site in 2006, 2007, 2014 and 2015 and failed to record either of the two rare species observed by Wilson. In the present study, only one site visit was made, in June 2016, in good weather, and again no records of *D. nebulosa* or *R. triangularis* were obtained. In the present study only eight species were observed (Appendix 1.1). Wilson (1995) provided a photograph of the site in which far more emergent vegetation – good dragonfly habitat – is evident than has existed in recent years.

8. Kang Mun Tsui (N 22º30.066', E 114º17.448'. 2m asl. Surveyed 20-06-16)

This remote pond with a broad weedy margin in the northeast New Territories was listed as a key dragonfly site by Wilson (1997a) due to it supporting a good range of common pond species along with a population of the libellulid *Rhyothemis triangularis*, which at that time was known from only three other sites in Hong Kong.

The remote nature of the pond restricted opportunities to make field visits and only one such visit was made, in June 2016. The pond had well forested banks and a shallow area at the northern end with dense emergent grasses providing good dragonfly habitat. Only 14 species were recorded (Appendix 1.1); *R. triangularis* was however reconfirmed at the site, and two other species with scattered distributions in the territory – *Nannophyopsis clara* and *Rhodothemis rufa* – were recorded apparently for the first time.

9. Lung Tsai Ng Yuen (N 22º14.104', E 113º52.143'. 220m asl. Surveyed 05-07-16)

Wilson (1997a) reported a thriving population of the coenagrionid *Paracercion calamorum* at this large lily pond in southwest Lantau, situated within South Lantau Country Park. At the time, this species was known from only two other Hong Kong sites (Tan Shan River and Tai Tong). Wilson (1997a) considered that the site was possibly the largest lily pond in Hong Kong.

The site was visited on one occasion in July 2016, during which the presence of *P. calamorum* was reconfirmed. A total of 17 odonate species was recorded (Appendix 1.1). *Leptogomphus hongkongensis* Asahina, 1988, a species of conservation interest (Reels 2019) recorded at or near the pond by Wilson, was not seen in the present study.

10. Tan Shan River ("River Jhelum" of Wilson 1997a) (N 22º30.453', E 114º10.403'. 20m asl. Surveyed 13-06-16, 14-06-16, 23-05-17)

This is a large meandering lowland stream in the northeast New Territories. Wilson (1997a) emphasised the remarkable fact that this water body remained relatively

unpolluted, despite it draining a densely populated agricultural area, and strongly recommended that the water quality be maintained and that the river should be accorded SSSI status. A number of locally rare species were reported from the site by Wilson (1997a), including *Paracercion calamorum*, *Pseudagrion spencei* Fraser, 1922, *Labrogomphus torvus* Needham, 1931, *Nannophyopsis clara*, *Rhodothemis rufa* and *Urothemis signata*.

The river was surveyed for dragonflies on three occasions, focusing on the long, mainly unchannelised upstream section between Sha Tau Kok Road and the foot of the hillside at the back of the valley (leading to Hok Tau Reservoir). This stretch of the river was not obviously heavily polluted and provided excellent dragonfly habitat, supporting 43 species (Appendix 1.1). *P. spencei*, *L. torvus* and *N. clara* were not observed, although a record was made of *Onychothemis testacea* Laidlaw, 1902, a species of conservation interest (Reels 2019), in 2016. Several individuals of this species were also observed at this river in 2017 (Ken So, pers. comm.).

11. Nam Chung (N 22º31.171', E 114º12.288'. 1m asl. Surveyed 23-05-16, 12-06-17)

This coastal site in the northeast New Territories comprises a mosaic of mangrove, fish ponds and lowland stream. Wilson (1997a) designated it a key dragonfly site on the presence of the mangrove-associated libellulid *Orthetrum poecilops*.

The site was visited on two dates, with *O. poecilops* reconfirmed in mangrove areas on both occasions. The similarly salt-tolerant coenagrionid *Mortonagrion hirosei* was also present in the same habitat. Both species are of conservation interest (Reels 2019). A total of 26 species was recorded (Appendix 1.1).

12. Tai Tong Stream (N 22º24.266', E 114º01.366'. 25m asl. Surveyed 25-04-16, 24-06-16)

This shallow gradient stream with sand/gravel bottom substrate near Yuen Long, partly situated within Tai Lam Country Park, was designated a key dragonfly site by Wilson (1997a) due primarily to the presence of two gomphids: *Paragomphus capricornis* (Förster, 1914), which was abundant at Tai Tong and was not known from elsewhere in the territory, and "*Lamelligomphus hongkongensis*", which at the time was thought to be endemic to Hong Kong but was subsequently determined to be the same taxon as *Lamelligomphus hainanensis* (Chao, 1953), of which it is a junior synonym (Wilson & Reels 2001). Wilson (1997a) also noted the presence of other stream species with burrowing larvae such as *Macromia urania* Ris, 1916, *Burmagompus vermicularis* (Martin, 1904) and *Megalogomphus sommeri* (Selys, 1854). An unsuccessful application for the site to be accorded SSSI status on the basis of its dragonfly fauna was made by WWF Hong Kong in the mid-1990s.

Wilson (1997b) listed 51 species from Tai Tong. In the present study, the site was visited two times and a total of 34 species recorded (Appendix 1.2). The species of interest noted by Wilson (1997a) were, with the exception of *L. hainanensis*, reconfirmed in the present study. *P. capricornis* was particularly abundant. Although the overall species total has apparently declined dramatically, the upper section of the stream (located within Tai Lam Country Park) remains more or less pristine. The lower section, however, is somewhat disturbed by activities connected to the lychee orchard and leisure park that occupies the land on either side. A number of pigs, goats and

other large animals are kept on the premises and their dung is cast onto the stream banks and into the stream. Nevertheless, this organic pollution does not seem to have impacted the larvae of gomphids such as *Asiagomphus hainanensis*, *Burmagomphus vermicularis*, *Megalogomphus sommeri* and, particularly, *Paragomphus capricornis*, all of which were numerous in the sand/gravel substrate, and with the exception of *Lamelligomphus hainanensis* the species that were not reconfirmed at the site in the present study were of little or no conservation interest.

13. Sha Lo Tung Basin (N 22º28.516', E 114º11.018'. 160m asl. Surveyed 20-04-16, 21-04-16, 12-05-16, 23-06-16, 11-05-17, 08-06-17, 26-06-17)

Wilson (1997a, 1997b) convincingly demonstrated that this marshy upland basin drained by shallow gradient streams near Tai Po was Hong Kong's most important dragonfly site, supporting numerous stream species of conservation interest including *Macromia katae* Wilson, 1993 and *Macromidia ellenae* (for both of which Sha Lo Tung is the type locality), *Gomphidia kelloggi* Needham, 1930, *Leptogomphus hongkongensis*, *Ophiogomphus sinicus* (Chao, 1954) and *Sieboldius alexanderi* Chao, 1955. In 1997 the site was designated an SSSI on the strength of its importance as a dragonfly site.

Wilson (1997b) listed 68 species from the site. In the present study, I made seven survey visits but was unable to record anywhere near this total, recording just 43 species (Appendix 1.2). Neither *M. ellenae* nor *L. hongkongensis* were observed. Eight of the 11 species of Gomphidae reported by Wilson (1997b) were, however, reconfirmed. *G. kelloggi* is still thriving in the streams of the basin. The shortfall in the present study included many typical pond/standing water species such as *Anax guttatus* (Burmeister, 1839), *Anax nigrofasciatus* Oguma, 1915, *Anax parthenope* (Brauer, 1865), *Epophthalmia elegans* and several libellulids, but also important forest species such as *Drepanosticta hongkongensis*, *Protosticta taipokauensis* and *Leptogomphus hongkongensis*. Much of the basin was wetter and marshier in the 1990s and early 2000s than today, the process of vegetation succession having dried it out to some extent. In the 1990s the site was often used illegally by off-road driving enthusiasts, and the wheel ruts and depressions left by their vehicles created small pool habitats in the open abandoned farmland that were colonised by many lentic dragonflies. Such open water areas subsequently disappeard, although in 2017 local villagers re-created flooded paddyfields in a part of the site, attracting species such as *Brachythemis contaminata* (Fabricius, 1793) and *Potamarcha congener*. The failure to reconfirm several important forest species is more difficult to explain. *Leptogomphus hongkongensis* was quite easy to find in small forested streams at the Hok Tau site (between Sha Lo Tung and Hok Tau Reservoir) but not in the basin itself, while the platystictids *D. hongkongensis* and *P. taipokauensis* were not encountered at either site in the present study. The forest habitat has not deteriorated, however, and there seems no reason for these species to have disappeared from the site. Perhaps they were present but unfortunately not observed in the present study.

14. Wu Kau Tang (N 22º30.347', E 114º14.596'. 100m asl. Surveyed 26-04-16, 27-04-16, 11-05-16, 26-07-16, 09-05-17, 10-05-17, 11-05-17, 28-06-17)

Wilson (1997a) designated Wu Kau Tang (and nearby Bride's Pool) a key dragonfly

site due to the presence of many important stream species including *Macromia katae* and *Macromia urania*, in addition to *Prodasineura croconota* (Ris, 1916) which appears to be restricted in Hong Kong to the northeast New Territories. The site is relatively poor in gomphids; however, *Fukienogomphus choifongae* Wilson & Tam, 2006 was described from Wu Kau Tang and has not been recorded from elsewhere in Hong Kong (and only from one other site in Guangdong). This further enhanced the site's importance, as did the discovery there of *Planaeschna skiaperipola* Wilson & Xu, 2008, also not subsequently reported from elsewhere in Hong Kong.

This extensive site was visited eight times and 42 species were recorded, including species of conservation interest such as *Protosticta taipokauensis* Asahina & Dudgeon, 1987, *Fukienogomphus choifongae* (by Bergman Ng) and *Sieboldius alexanderi* (Appendix 1.2). *P. skiaperipola* was not recorded in the present study.

15. She Shan Stream (N 22º26.895', E 114º08.504'. 22m asl. Surveyed 28-04-16, 21-06-16, 23-05-17)

Located in the Lam Tsuen valley near Tai Po, this is another shallow gradient stream, with mud/gravel substrate suitable for burrowing gomphid larvae. Wilson (1997a) listed it as a key dragonfly site due primarily to the presence of *Onychothemis testacea*, a stream libellulid at that time known from no other site in Hong Kong or China. Wilson also recorded *Labrogomphus torvus*, in which the larva, unusually, has an elongated abdominal segment nine that permits it to extract oxygen from the water whilst deeply buried in mud.

The site was visited three times. Habitat degradation may have afflicted the dragonfly community composition of the stream, with road and intensive village house construction along or near the stream banks in the past 20 years. Three species of conservation interest (*Asiagomphus hainanensis*, *Leptogomphus hongkongensis* and *Onychothemis testacea* (Reels 2019)) were not reconfirmed in the present study. Neither was *Labrogomphus torvus*, the previous presence of which was a major reason for this stream being designated a key dragonfly site (Wilson, 1997a). Much effort was fruitlessly expended in trying to find *L. torvus* larvae. A total of 27 species was recorded (Appendix 1.2).

16. Sham Tseng, upstream of settlement basin (N 22º22.334', E 114º03.238'. 110m asl. Surveyed 02-06-16, 07-07-16, 29-05-17)

This site, a shallow gradient, well-wooded stream in Tai Lam Country Park, draining into a small reservoir near Sham Tseng in the western New Territories, was identified as a key dragonfly site on the basis of it supporting "a good range of species including *Macromia berlandi* and several other corduliids" (Wilson 1997a). Wilson was presumably referring to *Epophthalmia elegans* (Brauer, 1865), *Idionyx victor* Hämäläinen, 1991 and *Macromidia rapida* Martin, 1906, which were among the species he recorded at this site in the period 1991-1997. Interestingly, Wilson seems to have recorded no riverine gomphids at this excellent gravel/sandy-bottomed stream, other than *Megalogomphus sommeri*.

The stream was found to be very gomphid-rich in 2016-2017, larval and adult sampling resulting in eight species being recorded, including two (*Leptogomphus hongkong-*

ensis and *Ophiogomphus sinicus*) listed as species of conservation interest by Reels (2019). Numerous perched gomphid adults were seen high in the riparian woodland and could not be identified or even approached. A population of the tiny libellulid *Nannophyopsis clara* is established in the emergent grasses where the stream enters the reservoir. A total of 33 species was recorded in the three surveys conducted (Appendix 1.2).

17. Upstream Tai Lam Reservoir (N 22º23.441', E 114º02.471'. 80m asl. Surveyed 09-05-16, 04-07-16, 26-05-17)

"A good range of upland stream species including *Megalogomphus sommeri* and *Burmagomphus vermicularis*. Huge numbers of *Neurobasis chinensis*" (Wilson 1997a).

This clean rocky hill stream draining into the northeast end of Tai Lam Reservoir in Tai Lam Country Park was visited three times. *Megalogomphus sommeri* and *Neurobasis chinensis* (Linnaeus, 1758) were both reconfirmed from the site (in small numbers), but *Burmagomphus vermicularis* was not recorded. Other notable records included the large aeshnid *Polycanthagyna erythromelas* (McLachlan, 1896), the conservation-interest species *Leptogomphus hongkongensis* (in a narrow tributary stream), and *Macromia berlandi*. Totally 23 species were recorded (Appendix 1.2).

18. Keung Shan (N 22º13.734', E 113º52.168'. 300m asl. Surveyed 05-07-16, 21-06-17)

This wooded mountain ravine stream in southwest Lantau (situated within South Lantau Country Park) is the type locality for *Protosticta beaumonti* Wilson, 1997 and also supports a population of *Sinosticta ogatai* (Matsuki & Saito, 1996) (Wilson 1997a). In addition to these two very important Hong Kong species, *Polycanthagyna erythromelas* is common here. Wilson (1997a) also reported the conservation-interest species *Leptogomphus hongkongensis* and *Melligomphus guangdongensis* (Chao, 1994) at this site and recommended that it be designated an SSSI.

The site was visited on two dates. *Protosticta beaumonti*, *Polycanthagyna erythromelas* and *L. hongkongensis* were reconfirmed, although *S. ogatai* was not observed. The habitat remained undisturbed. Moderate to heavy rain unfortunately suppressed odonate activity on both survey dates. A total of just 13 species was recorded (Appendix 1.2).

19. Ng Tung Chai (N 22º25.605', E 114º07.912'. 300m asl. Surveyed 07-06-16, 17-05-17, 18-05-17)

This steep wooded ravine situated within Tai Mo Shan Country Park on the northeastern flank of Tai Mo Shan is an SSSI and Special Area. Wilson (1997a) designated it a key dragonfly site on the presence of *Sinosticta ogatai* (for which Ng Tung Chai is the type locality), the montane platycnemidid *Calicnemia sinensis* Lieftinck, 1984, *Idionyx claudia* Ris, 1912 (known in Hong Kong only from Ng Tung Chai) and several gomphid species (including *Heliogomphus scorpio* (Ris, 1912), *Ophiogomphus sinicus* and *Stylogomphus chunliuae* Chao, 1954). Three species of Platystictidae were present (*S. ogatai*, *Drepanosticta hongongensis* Wilson, 1997 and *Protosticta taipokauensis*). The site's importance was further emphasised by the discovery of the forest aeshnid *Cephalaeschna klotsae* Asahina, 1982 in 2003. This species has not been found elsewhere in Hong Kong.

The site was visited on three dates (two in poor weather) and 20 species were recorded (Appendix 1.2). Most of the important species recorded by Wilson (1997a) were reconfirmed, including the three platystictids, *Calicnemia sinensis* and *S. chunliuae*. No record was made of *O. sinicus* or *I. claudia* (or of *Cephalaeschna klotsae* by me; however the species was observed at the site in 2016 (Mahler Ka, pers. comm.). One other species of conservation interest, *Melligomphus guangdongensis*, was recorded in the present study but not by Wilson (1997a).

20. Tai Mo Shan South (N 22º23.274', E 114º08.361'. 250m asl. Surveyed 31-05-16, 27-06-16, 06-06-17)

This is a steep upland area with small streams in woodland on the southern slope of Tai Mo Shan (within Tai Mo Shan Country Park); also the large Tai Shing stream, of which the smaller streams are tributaries, draining into Shing Mun Reservoir. Designated as a key dragonfly site by Wilson (1997a) on the basis of good populations of *Sinosticta ogatai* and *Calicnemia sinensis*, along with *Drepanosticta hongongensis* and *Zygonyx asahinai* Matsuki & Saito, 1995 (both of which were described from Hong Kong). Wilson believes he saw *Philosina alba* Wilson, 1999 (Philosinidae) on this stream in the late 1990s (a species not known from Hong Kong with which he was familiar from sites elsewhere in southeastern China) but was unfortunately unable to voucher it (Wilson, pers. comm.).

Three visits were made to the area, and 19 species were recorded (Appendix 1.2). Three species of conservation interest recorded by Wilson were not observed in 2016-2017: *C. sinensis*, *Protosticta taipokauensis* and *Ophiogomphus sinicus*. However, *Leptogomphus hongkongensis* and, notably, *Rhipidolestes janetae* Wilson, 1997 were recorded in the present study but not in Wilson (1997a).

21. Tai Po Kau (N 22º25.358', E 114º10.457'. 200m asl. Surveyed 03-05-16, 04-05-16, 07-06-17, 23-06-17)

This forest stream site near Tai Po is a Special Area and is situated within a Country Park. Wilson (1997a) designated it a key dragonfly site for its diverse species community, including *Melligomphus guangdongensis* (which at that time was believed to be an endemic Hong Kong species, "*Melligomphus moluami*"), *Drepanosticta hongkongensis*, *Polycanthagyna erythromelas* and two species for which Tai Po Kau is the type locality: *Protosticta taipokauensis* and *Zygonyx asahinai*.

The site was visited on four dates and 29 species were recorded (Appendix 1.2). Key species including *Agriomorpha fusca* May, 1933, *D. hongkongensis*, *P. taipokauensis*, *M. guangdongensis* and *Z. asahinai* were all reconfirmed, and several other species of interest (*Calicnemia sinensis*, *Sieboldius alexanderi* and *Anotogaster* sp. cf *klossi*) were recorded (the latter from a larva collected in 2016 by Tommy Hui).

22. Sunset Peak (N 22º15.610', E 113º57.360'. 560m asl. Surveyed 29-06-16, 27-06-17)

This is an area of submontane forest at 600m asl on the northern slope of Sunset Peak, Lantau, situated within North Lantau Country Park (the area is also an SSSI). Several tiny streams and seeps are present at which Wilson (1997a) recorded four particular species of conservation interest, on the basis of which he designated the

area a key dragonfly site: *Rhipidolestes janetae* (for which Sunset Peak is the type locality), *Calicnemis sinensis*, *Drepanosticta hongkongensis* and *Sinosticta ogatai*.

The site was visited on two dates, and all four of the species highlighted by Wilson (1997a) were reconfirmed, as was *Agriomorpha fusca*. In addition, *Protosticta beaumonti*, another species of conservation interest, was found to be present in good numbers. A total of 15 species was recorded (Appendix 1.2).

Additional sites

A total of eleven additional sites was added to the 22 "key dragonfly sites" for surveying in the present study. These were selected to reflect the same range of habitat types (steep forested hill stream, shallow gradient lowland stream, pond, freshwater marsh, coastal mangrove) in order to facilitate comparison with the key sites. In two cases the sites selected were contiguous with a key site.

23. Sheung Tsat Muk Kiu (N 22º30.198', E 114º13.340'. 250m asl. Surveyed 19-04-16, 16-05-16, 08-05-17)

This is a very small (ca 0.25 ha) marshy abandoned paddyfield site in Pat Sin Leng Country Park, located approximately 200m to the west of Pat Sin Leng Site 2. The site was chosen for comparison with key dragonfly sites Pat Sin Leng Sites 1 and 2. It was visited on three dates (and on one date by Ken So) in the present study. Eight species were recorded (Appendix 1.3). The site is wetter than Pat Sin Leng Sites 1 and 2 and currently supports populations of both *Lestes nodalis* and *Nannophya pygmaea*, the two species for which those two sites were considered important by Wilson (1997a). Both species were recorded in 2016 and 2017. Larvae of *N. pygmaea* were found to be very abundant in 2016, with *Lyriothemis elegantissima* Selys, 1883 larvae also present. A tandem pair of *Anax immaculifrons* Rambur, 1842 was observed at the site in May 2017, the female ovipositing into submerged vegetation.

24. Kai Kuk Shue Ha (N 22º31.438', E 114º13.224'. 5m asl. Surveyed 17-04-16, 11-05-16, 24-05-16, 25-05-17)

This is a weedy pond/marsh complex with a shallow gradient lowland stream flowing beside it, located immediately to the northeast of Luk Keng marsh, from which it is separated by the Bride's Pool Road. The site was chosen for comparison with similar habitat key dragonfly sites such as Luk Keng, Ma Tso Lung, Lamma Pond, Kang Mun Tsui and Lung Tsai Ng Yuen. The pond immediately to the northeast of the road was, in the early 2000s, an exceptionally good dragonfly pond, with thriving populations of *Paracercion melanotum* (Selys, 1876), *Nannophyopsis clara*, *Rhodothemis rufa* and *Urothemis signata*. The marshy pond adjacent to it supported *Rhyothemis triangularis* and the marshy abandoned paddies beyond that supported *Nannophya pygmaea*. The first pond was partially infilled by a villager some years later and its value as dragonfly habitat declined accordingly. By the time of the present study, however, the site had recovered to some extent. It was visited on four dates and 33 species were recorded (Appendix 1.3), including *P. melanotum*, *Onychargia atrocyana*, *Rhodothemis rufa*, *Rhyothemis triangularis* (which was

abundant) and *U. signata*. The recent arrival *Aethriamanta brevipennis* was also present. Unfortunately, neither *Nannophyopsis clara* nor *Nannophya pygmaea* were observed in the present study.

25. Kuk Po (N 22º31.634', E 114º14.031'. 2m asl. Surveyed 16-06-16, 22-06-17)

This is a large salt/freshwater marsh complex with a shallow gradient stream at Starling Inlet, a few kilometres to the northeast of Luk Keng. The site was chosen for comparison with similar habitat key dragonfly sites such as Luk Keng, Yung Shue O, Shuen Wan and Nam Chung. It was visited on two dates and a total of 29 species recorded (Appendix 1.3), including *Aethriamanta brevipennis*, *Macrodiplax cora* (Kaup in Brauer, 1867), *Potamarcha congener* and the salt-tolerant *Mortonagrion hirosei* and *Orthetrum poecilops* (both in the mangrove/reedbed at the coastal side of the site). *O. poecilops* was also observed at several other coastal mangrove patches between Luk Keng and Kuk Po.

26. Nam Sang Wai (N 22º27.417', E 114º02.042'. 2m asl. Surveyed 01-06-17)

An extensive area of former fish ponds to the north of Yuen Long, many of the ponds now densely vegetated with no open water. The site was chosen for comparison with the similar habitat key dragonfly site Ma Tso Lung. Most open water areas were difficult to access because of the tall vegetation. The site was visited on one date, in less than ideal conditions (overcast and very windy) and only six species were observed (Appendix 1.3).

27. Yuen Leng Chai (N 22º31.946', E 114º07.109'. 5m asl. Surveyed 21-06-16, 29-06-17)

This is a large abandoned pond with a central island and adjacent freshwater marsh lying in the former Frontier Closed Area immediately to the east of Lo Wu. It was chosen for comparison with similar habitat key dragonfly sites Ma Tso Lung, Lamma Pond and Kang Mun Tsui. The site was visited on two dates and was found to support large populations of many pond libellulids including *Aethriamanta brevipennis*, *Rhodothemis rufa*, *Rhyothemis triangularis* and *Urothemis signata*. A total of 23 dragonfly species was recorded at the site (Appendix 1.3).

28. Hong Kong Wetland Park (N 22º28.108', E 114º00.277'. 1m asl. Surveyed 23-06-16)

This extensive managed pond/marsh complex has been thoroughly studied and monitored by the Hong Kong Agriculture, Fisheries and Conservation Department (AFCD). It was chosen for comparison with similar habitat key dragonfly sites such as Luk Keng, Ma Tso Lung, Yung Shue O, Shuen Wan, Lamma Pond, Kang Mun Tsui and Lung Tsai Ng Yuen. Only a single site visit was conducted in which 21 species were recorded, including *Pseudagrion microcephalum* (Rambur, 1842) and *Aethriamanta brevipennis*. These records are augmented in Appendix 1.3 with a 2016 record of the scarce libellulid *Trithemis pallidinervis* (Edmond Sham, pers. comm.) and a 2017 record of *Zyxomma petiolatum* Rambur, 1842 and the scattered *Potamarcha congener* (Bergman Ng, pers. comm.).

29. Hok Tau (N 22º29.142', E 114º10.967'. 130m asl. Surveyed 20-04-16, 12-05-16, 30-05-16, 08-06-17)

An area of good secondary woodland drained by rocky streams descending from the Sha Lo Tung basin, with which it is contiguous, and adjacent uplands to Hok Tau Reservoir. It was chosen for comparison with similar habitat key dragonfly sites such as Upstream Tai Lam, Keung Shan, Ng Tung Chai, Tai Mo Shan South and Tai Po Kau. The site was visited on four dates, and 31 species of dragonfly were recorded. These records are augmented in Appendix 1.3 with three significant additional records: *Labrogomphus torvus* in 2017 (Bill Ho, pers. comm.) and *Macromidia ellenae* and *Nannophyopsis clara*, also in 2017 (Bergman Ng, pers. comm.). Eleven species of Gomphidae were recorded in total, either as larvae or adult or both, including several (*Gomphidia kelloggi*, *Leptogomphus hongkongensis*, *Melligomphus guangdongensis*, *Ophiogomphus sinicus* and *Sieboldius alexanderi*) considered of conservation interest (Reels 2019). *Macromia katae* was also present.

30. Man Uk Pin (N 22º31.693', E 114º10.919'. 30m asl. Surveyed 06-05-16, 29-06-17)

A shallow gradient lowland stream in the rural northeast New Territories, with a mixed substrate of cobbles and sand/gravel. Chosen for comparison with similar habitat key dragonfly sites such as Tan Shan River, Tai Tong Stream, Wu Kau Tang and She Shan Stream. The site was visited on two dates and 29 species were recorded (Appendix 1.3), including the gomphids *Burmagomphus vermicularis* and *Megalogomphus sommeri*.

31. Tai Shui Hang (N 22º24.492', E 113º56.492'. 30m asl. Surveyed 02-05-16, 14-05-16)

This extensive site includes the wet agricultural fields of Tai Shui Hang in the far western New Territories and the very large Tsing Tai Stream which drains the poorly forested nearby uplands of the military firing range. The stream is very broad and slow-flowing at the lower reaches with a substrate predominantly composed of coarse gravel. Chosen for comparison with similar habitat key dragonfly sites such as Tan Shan River, Tai Tong Stream and She Shan Stream. The site was visited on two dates. Intensive larval sampling yielded no odonate larvae. It was also notable that few if any fish were observed. However a reasonable total of 26 dragonfly species was recorded as adults, including *Paragomphus capricornis*, the larvae of which are sand/-gravel burrowers (Appendix 1.3). A notable additional record was of *Aciagrion approximans*, observed at Tai Shui Hang in both 2016 and 2017 (Bergman Ng, pers. comm.). This species was hitherto known in Hong Kong only from Pat Sin Leng Site 2, a location from which it now appears to be absent.

32. Hang Cho Stream (N 22º23.767', E 114º16.055'. 130m asl. Surveyed 05-06-17)

A forested rocky hill stream near Po Lo Che in Sai Kung. The site was chosen for comparison with similar habitat key dragonfly sites such as Upstream Tai Lam, Keung Shan, Ng Tung Chai, Tai Mo Shan and Tai Po Kau. A single speculative field trip was made to this site in June 2017. The habitat was undisturbed and the weather conditions fine but only 11 species were recorded, including *Leptogomphus hongkongensis* (Appendix 1.3).

33. Double Island (N 22°31.045', E 114°19.009'. 0m asl. Surveyed 20-06-16)

This small mangrove and salt marsh on the east coast of Double Island is a known site for the salt-tolerant species *Mortonagrion hirosei* and *Orthetrum poecilops* (Tam et al. 2008). It was chosen for comparison with similar habitat key dragonfly sites such as Luk Keng, Yung Shue O, Shuen Wan and Nam Chung. The island is remote and access is not simple; however a single field trip was undertaken in June 2016 to reconfirm the presence of these two species of conservation interest. Weather conditions were favourable but only *O. poecilops* was reconfirmed in the visit (Appendix 1.3).

Kai Kuk Shue Ha. A pond, marsh and stream complex adjacent to Luk Keng supporting 33 lentic species including *Aethriamanta brevipennis* and *Rhyothemis triangularis*.

Small shallow gradient stream at Kai Kuk Shue Ha.

Lamma Island pond. A site that has deteriorated since the 1990s. Only eight species recorded here in the present study.

Cheung Sheung marsh. Not surveyed in the present study but Hong Kong's only site for *Agriocnemis lacteola*.

Luk Keng marsh. The largest unmanaged freshwater marsh in Hong Kong. Thirty-five species including the tiny libellulid *Nannophyopsis clara* recorded during the study.

Estuarine mangrove at Double Island. A good site for *Orthetrum poecilops*.

Kang Mun Tsui. A large, remote pond in the northeast of Hong Kong. *Nannophyopsis clara* present in emergent grasses at this pond but only 14 species in total recorded.

Mangrove and reedbed at Kuk Po. Good habitat for the salt-tolerant species *Mortonagrion hirosei* and *Orthetrum poecilops*.

Freshwater marsh at Kuk Po. Totally 29 species were recorded in the mosaic of stream, freshwater marsh and salt marsh at this site.

Pat Sin Leng Site 1. Formerly an important site for *Lestes nodalis* but the marsh here is increasingly choked with vegetation. Only eight species recorded here in the present study.

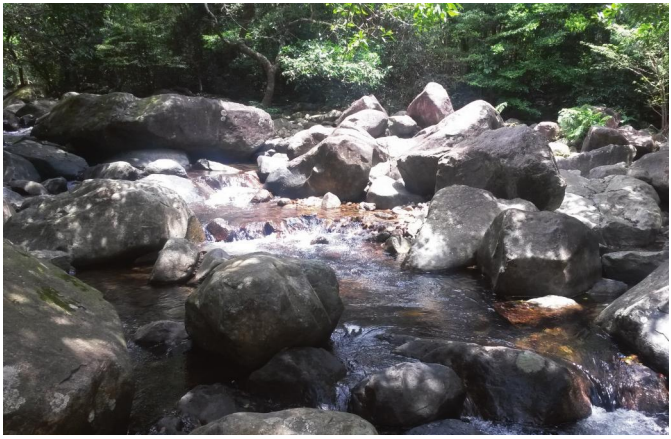
Pat Sin Leng Site 2. Formerly an important site for *Nannophya pygmaea* but the marsh here has now almost completely dried up.

Tai Shui Hang. A large, gravelly lowland stream in the northwest of Hong Kong, supporting populations of *Neurobasis chinensis* and *Paragomphus capricornis*. 26 species recorded.

Downstream section of Tai Tong stream. A gravel-bottomed lowland stream with good riparian vegetation supporting 34 species. Particularly notable for the large population of *Paragomphus capricornis*. Subject to organic pollution from livestock.

Pristine upstream section of Tai Tong stream.

Large boulder stream at Tai Mo Shan South. *Tetracanthagyna waterhousei* recorded here.

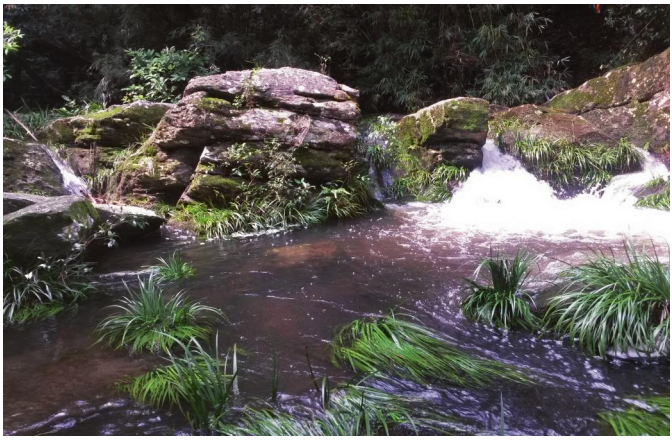


Upstream of Tai Lam Reservoir. A fast-flowing boulder stream at which 23 species were recorded. Good population of *Megalogomphus sommeri* at this site.

Brackish mangrove and sedges at Shuen Wan. 20 species recorded at this site, including *Onychargia atrocyana* and the salt-tolerant libellulid *Orthetrum poecilops*.

Sha Lo Tung basin. An upland marsh / stream complex at which 43 species were recorded in the present study. Long regarded as Hong Kong's richest dragonfly site.

Wet paddy fields newly established in Sha Lo Tung in 2017, attracting *Potamarcha congener* and other pond species.



Shallow gradient boulder / cobble stream at Wu Kau Tang. 42 species were recorded in the stream / marsh complex of habitats at this site.

Ranking species and sites of conservation importance

In addition to the 33 sites considered separately above, two composite sites are suggested here: Luk Keng/Kai Kuk Shue Ha (LK/KKSH) and Sha Lo Tung/Hok Tau (SLT/HT). In both cases these paired sites lie adjacent to each other and form contiguous areas. The 35 sites are ranked below on the basis of crude species richness and a conservation value metric.

Site evaluation using dragonfly species richness

Overall species richness and number of conservation interest species (cf Reels 2019) at the 35 sites are ranked in Table 1.

Rank	Site	Overall species richness
1	SLT/HT	54
2	LK/KKSH	46
3=	Tan Shan River Sha Lo Tung	43
5	Wu Kau Tang	42
6	Luk Keng	35
7=	Tai Tong Stream Hok Tau	34
9=	Ma Tso Lung Kai Kuk Shue Ha	33
11	Sham Tseng	32
12=	Tai Po Kau Kuk Po Man Uk Pin	29
15	She Shan Stream	27
16=	Nam Chung Tai Shui Hang	26
18	Wetland Park	24
19=	Yung Shue O Upstream Tai Lam Yuen Leng Chai	23
22=	Shuen Wan Ng Tung Chai	20
24	Tai Mo Shan South	19
25	Lung Tsai Ng Yuen	17
26	Kang Mun Tsui	14
27=	Keung Shan Sunset Peak	13
29	Hang Cho	11
30=	Pat Sin Leng Site 1 Lamma Pond Sheung Tsat Muk Kiu	8
33	Nam Sang Wai	6
34=	Pat Sin Leng Site 2 Double Island	5

Rank	Site	Conservation interest species
1	SLT/HT	12
2=	Sha Lo Tung Tai Po Kau Hok Tau	9
5	Ng Tung Chai	7
6=	Wu Kau Tang Tai Mo Shan South	6
8	Sunset Peak	5
9=	LK/KKSH Sham Tseng	4
11=	Luk Keng Tan Shan River	3
13=	Yung Shue O Nam Chung Shuen Wan Tai Tong Keung Shan Kuk Po	2
19=	Upstream Tai Lam Sheung Tsat Muk Kiu Kai Kuk Shue Ha Man Uk Pin Tai Shui Hang Hang Cho Double Island	1
26=	Pat Sin Leng Site 1 Pat Sin Leng Site 2 Ma Tso Lung Lung Tsai Ng Yuen Lamma Pond Kang Mun Tsui She Shan Stream Nam Sang Wai Yuen Leng Chai Wetland Park	0

Table 1. Dragonfly species richness and no. of conservation interest (cf Reels 2019) ranked at 35 sites, 2016-2017.

SLT/HT = Sha Lo Tung/Hok Tau; LK/KKSH = Luk Keng/Kai Kuk Shue Ha composite sites.

The composite site SLT/HT comfortably ranks in first place in species richness, both overall and specifically in conservation-interest species (Table 1). Sha Lo Tung comes 3rd in both rankings, while Wu Kau Tang is 5th for overall species richness and 6th for conservation-interest species. This is where the comparability ends at the top end of the rankings, however. As is evident from Table 1, overall species richness at a site can often only provide a very crude measure of site conservation value. Ng Tung Chai, for example, ranks only 22nd out of 35 for species richness but is 5th in terms of its conservation interest species. Similarly, Tai Mo Shan South is 24th for species richness but 6th for conservation interest species. Tai Po Kau, 2nd in the rankings for species of conservation interest, lies 12th in the rankings for overall species richness. In fact, only five of the top 10 most species-rich sites are also in the top 10 for species of conservation interest (Table 1).

Another problem with this approach is that it gives equal weighting to each species. In fact, there are degrees of importance for all species, especially those of conservation interest, depending on a variety of factors (rarity, restrictedness, taxonomic distinctiveness, level of percieved threat, etc.).

Site evaluation using a dragonfly species conservation value assessment metric

The quantity vs. quality conundrum in identifying and ranking key dragonfly species and sites, as exemplified by Table 1, can be resolved using a conservation value assessment metric. Wilson & Reels (1999) proposed such a metric for using dragonflies in wetland evaluation in tropical southern China. It was subsequently used by Reels (2013) to compare a range of sites across southeastern China. The metric assigns an aggregate value to each dragonfly species on the basis of a number of point-scoring categories. These can then be tallied up species by species to give an aggregate score for a particular site. A modified version of this metric was adopted in the present study (Reels 2019 and this paper), to make it appropriate to the Hong Kong context. Details of the metric and its application to Hong Kong dragonfly species were discussed in Reels (2019) and are provided in Appendix 2 of this paper. The aggregate metric score of all species present at a site can be used as an objective measure of the site's conservation importance. This is a combined measure of species richness and species' conservation value. Using this approach, the 22 "key dragonfly sites", 11 additional sites and two composite sites surveyed in the present study are ranked in Table 2.

In the present study, Sha Lo Tung attains easily the highest conservation value score of any of the key dragonfly sites identified by Wilson (1997a), but surprisingly it is surpassed by the contiguous adjacent Hok Tau site (an "additional site" in the present study). These sites occupy third and second positions, respectively, in Table 2; unsurprisingly the composite site Sha Lo Tung/Hok Tau far exceeds any other surveyed site in dragonfly conservation value. This accords well with Table 1. Forest sites dominate the top end of Table 2: the only site in the top 10 in which woodland is not an important (if not the only) habitat is the composite pond/marsh site, Luk Keng/Kai Kuk Shue Ha (in 9th position). This also is unsurprising, given that the majority of species of conservation interest listed in Reels (2019) are forest-associated. Several pond/marsh

Table 2. Metric ranking of Hong Kong dragonfly sites by conservation value.

Rank	Site	Score	Rank	Site	Score
1	SLT/HT	451	19	Nam Chung	90
2	Hok Tau	347	20	Tai Shui Hang	84
3	Sha Lo Tung	337	21	Kai Kuk Shue Ha	71
4	Tai Po Kau	276	22	Shuen Wan	70
5	Ng Tung Chai	270	23	Hang Cho Stream	67
6	Wu Kau Tang	254	24	Ma Tso Lung	51
7	Tai Mo Shan South	246	25	She Shan Stream	44
8	Sunset Peak	205	26=	Lung Tsai Ng Yuen Double Island	39
9	LK/KKSH	175			
10	Sham Tseng Stream	168	28=	Sheung Tsat Muk Kiu Hong Kong Wetland Park	30
11	Tai Tong Stream	136			
12	Luk Keng	130	30	Yuen Leng Chai	29
13	Tan Shan River	123	31	Kang Mun Tsui	23
14	Upstream Tai Lam Res.	106	32	Pat Sin Leng Site 2	18
15=	Keung Shan Man Uk Pin	100	33=	Pat Sin Leng Site 1 Lamma Pond	8
17	Kuk Po	99			
18	Yung Shue O	93	35	Nam Sang Wai	6

sites with high species richness such as Luk Keng, Ma Tso Lung and Kai Kuk Shue Ha (Table 1) score relatively low on the metric, as does the very species-rich Tan Shan River, because of the paucity of high conservation value species at those sites. Nevertheless they are important reservoirs of biodiversity.

Several of the sites scoring lowest in both Table 1 and Table 2 were only visited once during the present study. In some cases (Lamma Pond, Kang Mun Tsui, Double Island) this was because the sites were both small and remote. Such was not the case for Hong Kong Wetland Park or Nam Sang Wai, however, and these sites undoubtedly support many more species than were encountered in the present study. The Wetland Park has been particularly well studied by AFCD. Nevertheless, it is highly likely that the vast majority of species at these two sites that were missed in the present study would be low-scoring widespread pond coenagrionids, aeshnids and libellulids.

A revised list of key Hong Kong dragonfly sites

Of the 23 key dragonfly sites listed by Wilson (1997a), eight may be considered to no longer merit such status: Pat Sin Leng Sites 1 and 2 (both of which are in the process of drying out); Shuen Wan and Nam Chung (cited for *Orthetrum poecilops* by Wilson (1997a) but this species has subsequently spread to several more sites); Kau Sai, Kang Mun Tsui and Lamma ponds (all of which have declined in importance for various reasons); She Shan stream, at which habitat quality has deteriorated.

New additions to the list of key dragonfly sites

Five of the 11 additional sites surveyed in the present study are considered to merit the status of key dragonfly site, as does one site not visited in the present study. These are discussed below.

Sheung Tsat Muk Kiu

Surveyed to provide a comparison with the nearby Pat Sin Leng Sites 1 and 2, this site was found to support populations of the two important species now apparently absent from those two sites, *Lestes nodalis* and *Nannophya pygmaea*.

Kuk Po

This site was chosen to provide a comparison with the similar former key dragonfly sites Nam Chung and Shuen Wan. It supports good populations of the two salt-tolerant species *Mortonagrion hirosei* and *Orthetrum poecilops*, and ranks higher than both Nam Chung and Shuen Wan in terms of species richness (Table 1) and conservation value (Table 2).

Kai Kuk Shue Ha

This small pond/marsh site lying adjacent to Luk Keng has high species richness (9th= out of 35 sites; Table 1) and does not rank poorly in terms of conservation importance (21st out of 35 sites; Table 2). However, the main reason for its inclusion as a key dragonfly site is as part of a larger site incorporating Luk Keng. This composite site ranks 2nd in terms of species richness, where Luk Keng by itself ranks only 6th (Table 1) and 12th for conservation importance (Table 2).

Man Uk Pin

This shallow gradient lowland stream was compared against the former key dragonfly site She Shan Stream, which has deteriorated since the 1990s. It was found to be marginally more species-rich than She Shan Stream (Table 1) and to have a considerably higher conservation importance, scoring 100 on the metric as opposed to a score of 44 for She Shan Stream (Table 2).

Hok Tau

This remarkable woodland site occupying the slopes between the Sha Lo Tung basin and Hok Tau Reservoir was found to have a similar number of species of conservation interest to Sha Lo Tung (Table 1), and actually outscores Sha Lo Tung using the conservation value assessment metric (Table 2). Thus it would clearly merit inclusion in the list of key dragonfly sites even if it were not adjacent to Sha Lo Tung. When the two are considered as a composite site, however, the value is outstanding. By a very large margin, Sha Lo Tung/Hok Tau is the most important dragonfly site in Hong Kong, comfortably exceeding any other site in terms of species richness, number of species of conservation interest, and conservation value (Tables 1 and 2).

Cheung Sheung

This marshy upland site in the Sai Kung peninsula (N 22°25.735', E 114°18.391'; 300m asl.) was not surveyed in the present study, but it has been visited by the author

on numerous occasions, most recently in 2015. The site comprises an upland basin in which a shallow gradient stream, seasonal ponds and a permanent marsh are established. In the 1990s this site supported the only known breeding population of *Agriocnemis lacteola* Selys, 1877 in Hong Kong. Twenty years later this is still the case. Although *A. lacteola* is a widespread species in Asia the Cheung Sheung site with its long-established isolated population is important in the local Hong Kong context.

Hong Kong key dragonfly sites, 2017

The habitats represented in the key dragonfly sites recognised here include coastal wetlands incorporating mangrove, salt marsh and freshwater marsh, inland freshwater marsh sites, freshwater ponds, large lowland streams, shallow gradient upland streams, forested hill streams and mountain seepages that together cover all dragonfly species found in Hong Kong. They are listed in habitat order in Table 3.

Recommendations

(1) Of the 19 key dragonfly sites listed in Table 3, only 12 are currently protected or part-protected by virtue of being situated within a Country Park or Special Area or by virtue of being accorded SSSI status. Among the seven unprotected sites, six are recognised by the AFCD as being (or containing) "Ecologically Important Streams" – a status which unfortunately does not give statutory protection but does at least imply that developments at or near the streams need to be particularly sensitive to the stream habitat. It is recommended that Tai Tong Stream also be accorded this status.

(2) The Sheung Tsat Muk Kiu site, although protected by being situated within a Country Park, appears vulnerable to the same fate – naturally drying out – as the nearby Pat Sin Leng Sites 1 and 2 unless actively managed in the future by AFCD.

(3) The marshes that have developed on the abandoned paddyfields at the extensive, species-rich sites Sha Lo Tung and Wu Kau Tang could be significantly enhanced for dragonflies (and other aquatic fauna and flora) by creating permanent ponds, perhaps 25m in diameter, with shallow margins. Such ponds could be constructed and managed to establish zones of open water, zones with fully submerged rooted aquatic macrophytes, rooted aquatic macrophytes with floating leaves and marginal, emergent aquatic macrophytes. Such habitat, which is currently missing at both Sha Lo Tung and Wu Kau Tang, and rare in Hong Kong, would undoubtedly enhance populations of lentic dragonflies, including potentially the three weedy pond species – *Paracercion calamorum*, *Nannophya pygmaea* and *Palpopleura sexmaculata* – identified by Reels (2019) as having definitely declined in Hong Kong since the 1990s. Other marshy sites where a pond creation programme could be usefully implemented include Luk Keng, Yung Shue O and Kuk Po. Such a programme could, if properly managed, be of enormous benefit not only to dragonflies but also to other aquatic invertebrates, amphibians and waterfowl.

Table 3. Hong Kong key dragonfly sites, 2017.

Site / habitat	Attributes and current protection status
LOWLAND PONDS AND MARSHES	
Kuk Po, Starling Inlet, NENT. Coastal mangrove/ salt marsh/ freshwater marsh/stream.	Richness: 29 spp. Conservation interest spp.: 2 (*Mortonagrion hirosei*, *Orthetrum poecilops*). Metric score: 99. No current protection ("Ecologically Important Stream" - AFCD).
Yung Shue O, Three Fathoms Cove, Sai Kung. Coastal mangrove/salt marsh/ freshwater marsh/stream.	Richness: 23 spp. Conservation interest spp.: 2 (*Onychargia atrocyana*, *Orthetrum poecilops*). Metric score: 93. No current protection ("Ecologically Important Stream" - AFCD).
Luk Keng/Kai Kuk Shue Ha, Starling Inlet, NENT. Coastal mangrove/ salt marsh/ freshwater ponds/ marsh/stream.	Richness: 46 spp.. Conservation interest spp.: 4 (*Mortonagrion hirosei, Onychargia atrocyana*, *Macromidia ellenae*, *Orthetrum poecilops*). Metric score: 175. Part-protected as Conservation Area.
Ma Tso Lung, Lok Ma Chau, NWNT. Freshwater ponds/ marsh.	Richness: 33 spp. Conservation interest spp.: 0. Metric score: 51. Retained as key site due to high species richness of pond species. No current protection.
UPLAND PONDS AND MARSHES	
Lung Tsai Ng Yuen, Keung Shan, Lantau. Lily pond.	Richness: 17 spp. Conservation interest spp.: 0. Metric score: 39. Retained as key site due to important population of *Paracercion calamorum*. SSSI, Special Area, Country Park.
Sheung Tsat Muk Kiu, Pat Sin Leng Country Park, NENT. Freshwater marsh.	Richness: 8 spp. Conservation interest spp.: 1 (*Lestes nodalis*). Metric score: 30. Hong Kong's only confirmed breeding site for *Lestes nodalis*. Country Park. Given the similarity to Pat Sin Leng Sites 1 and 2, both of which are drying out, it appears that this site is particularly vulnerable.
Cheung Sheung, Enclave within Sai Kung West Country Park. Freshwater ponds/ marsh/ stream.	Not surveyed in present study. Hong Kong's only confirmed breeding site for *Agriocnemis lacteola*. No current protection ("Ecologically Important Stream" - AFCD).
LOWLAND RIVERS AND STREAMS	
Tan Shan River, near Fanling, NENT. Large shallow gradient stream, some natural stream bank preserved.	Richness: 43 spp. Conservation interest spp.: 3 (*Lamelligomphus hainanensis*, *Onychothemis testacea*, *Zygonyx asahinai*). Metric score: 123. No current protection ("Ecologically Important Stream" - AFCD).
Man Uk Pin, Sha Tau Kok Road, NENT. Shallow gradient stream, some natural stream bank preserved.	Richness: 29 spp. Conservation interest spp.: 1 (*Philoganga vetusta*). Metric score: 100. No current protection ("Ecologically Important Stream" - AFCD).
Tai Tong Stream, Yuen Long, NWNT. Shallow gradient stream, some natural stream bank preserved/ pond.	Richness: 34 spp. Conservation interest spp.: 2 (*Philoganga vetusta, Asiagomphus hainanensis*). Metric score: 136). Part-protected as Country Park.
SHALLOW GRADIENT UPLAND STREAMS	
Wu Kau Tang, Plover Cove, NENT. Gentle cobble streams/ marsh.	Richness: 42 spp. Conservation interest spp.: 6 (*Philoganga vetusta*, *Protosticta taipokauensis*, *Asiagomphus hainanensis*, *Fukienogomphus choifongae*, *Sieboldius alexanderi*, *Zygonyx asahinai*). Type locality of *F. choifongae* and only Hong Kong location for this species. Metric score: 254. No current protection (Part-zoned Conservation Area; "Ecologically Important Stream" - AFCD).
Sham Tseng Stream, near Tsing	Richness: 32 spp. Conservation interest spp.: 4 (*Asiagomphus*

Lung Tau, NWNT. Small reservoir/ gentle forest sand-gravel stream.	*hainanensis*, *Lamelligomphus hainanensis*, *Leptogomphus hongkongensis*, *Ophiogomphus sinicus*). Metric score: 168. Country Park.
FORESTED HILL STREAMS AND SEEPAGES	
Upstream Tai Lam Reservoir, Tai Lam Country Park, NWNT. Rocky hill stream.	Richness: 23 spp. Conservation interest spp.: 1 (*Leptogomphus hongkongensis*). Metric score: 106. Country Park.
Keung Shan, Lantau South Country Park. Small forest stream.	Richness: 13 spp. Conservation interest spp.: 2 (*Protosticta beaumonti*, *Leptogomphus hongkongensis*). Metric score: 100. Country Park.
Ng Tung Chai, Lam Tsuen Valley, CNT. Steep forest boulder stream/ seepages.	Richness: 20 spp. Conservation interest spp.: 7 (*Philoganga vetusta*, *Calicnemia sinensis*, *Drepanosticta hongkongensis*, *Protosticta taipokauensis*, *Sinosticta ogatai*, *Cephalaeschna klotsae*, *Melligomphus guangdongensis*). Metric score: 270. SSSI, Special Area, Country Park.
Tai Mo Shan South, Shing Mun, CNT. Large forest boulder stream/ small forest streams/ seepages.	Richness: 19 spp. Conservation interest spp.: 6 (*Philoganga vetusta*, *Rhipidolestes janetae*, *Drepanosticta hongkongensis*, *Sinosticta ogatai*, *Leptogomphus hongkongensis*, *Zygonyx asahinai*). Metric score: 246. Special Area, Country Park.
Tai Po Kau, Tai Po, CNT. Small man-made ponds/ large forest boulder stream/ small forest streams/ seepages.	Richness: 29 spp. Conservation interest spp.: 9 (*Calicnemia sinensis*, *Drepanosticta hongkongensis*, *Protosticta taipokauensis*, *Asiagomphus hainanensis*, *Leptogomphus hongkongensis*, *Melligomphus guangdongensis*, *Sieboldius alexanderi*, *Anotogaster* sp. cf *klossi*, *Zygonyx asahinai*). Metric score: 276. Special Area, Country Park.
Sunset Peak, Lantau North Country Park. Steep submontane forest streams/ seepages.	Richness: 13 spp. Conservation interest spp.: 5 (*Rhipidolestes janetae*, *Calicnemia sinensis*, *Drepanosticta hongkongensis*, *Protosticta taipokauensis*, *Sinosticta ogatai*). Metric score: 205. SSSI, Country Park.
SHALLOW GRADIENT UPLAND STREAMS/FORESTED HILL STREAMS	
Sha Lo Tung/Hok Tau, near Tai Po/Fanling, NENT. Reservoir/ gentle sand-gravel-cobble streams/ marsh/ wet paddyfield (created 2017)/ large forest stream/ small forest stream/ seepages.	Richness: 54 spp. Conservation interest spp.: 12 (*Philoganga vetusta*, *Onychargia atrocyana*, *Asiagomphus hainanensis*, *Gomphidia kelloggi*, *Lamelligomphus hainanensis*, *Leptogomphus hongkongensis*, *Melligomphus guangdongensis*, *Ophiogomphus sinicus*, *Sieboldius alexanderi*, *Macromia katae*, *Macromidia ellenae*, *Zygonyx asahinai*). Metric score: 451. Part SSSI, part Country Park ("Ecologically Important Stream" - AFCD (Sha Lo Tung)).

Concluding remarks

Habitat quality has deteriorated at several of the Hong Kong "key dragonfly sites" identified by Wilson (1997a). This deterioration has resulted variously from natural vegetation succession (Pat Sin Leng Sites 1 and 2), choking up of a pond with vegetation (Kau Sai pond), apparently natural reduction in submerged and emergent pond vegetation (Lamma pond) and presumed anthropogenic disturbance (She Shan stream). At the same time, several "key dragonfly sites" have declined in relative conservation value as the species formerly thought to be restricted to them have spread to, or at least been discovered at, other locations. However, the majority of Wilson's sites have been reconfirmed as being of continued importance. Four completely "new" key dragonfly sites are proposed here: a coastal marsh supporting both of Hong Kong's salt-tolerant species (Kuk Po; *Mortonagrion hirosei* and *Orthetrum poecilops*), two

upland marshes supporting locally significant dragonfly populations (*Lestes nodalis* at Sheung Tsat Muk Kiu and *Agriocnemis lacteola* at Cheung Sheung) and a lowland stream supporting a good variety of riverine species (Man Uk Pin). In addition, two of Wilson's key dragonfly sites are here expanded to include adjacent dragonfly-rich areas (Luk Keng to Luk Keng / Kai Kuk Shue Ha; Sha Lo Tung to Sha Lo Tung / Hok Tau).

Species-richness is only one measure of a dragonfly site's importance. A perhaps more informative measure is provided by use of a species conservation value metric. This combines crude species richness with an objective evaluation of aggregate conservation importance of a site's dragonfly community. The metric used in this study clearly identified Sha Lo Tung / Hok Tau as containing by far the most important dragonfly assemblage in Hong Kong.

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Appendix 1.1. Species recorded at sites 1-11.

Species/taxon	**Sites 1-11**										
	PSL1	PSL2	LKM	MTL	YSO	SW	LP	KMT	LTNY	TSR	NC
CALOPTERYGIDAE											
Mnais mneme Ris, 1916											
Neurobasis chinensis chinensis (Linnaeus, 1758)											
CHLOROCYPHIDAE											
Rhinocypha perforata perforata (Percheron, 1835)											
EUPHAEIDAE											
Euphaea decorata Hagen in Selys, 1853											
COENAGRIONIDAE											
Agriocnemis femina oryzae Lieftinck, 1962											
Agriocnemis pygmaea (Rambur, 1842)											
Ceriagrion auranticum ryukyuanum Asahina, 1967											
Ischnura senegalensis (Rambur, 1842)											
Mortonagrion hirosei Asahina, 1972											
Paracercion calamorum dyeri (Fraser, 1919)											
Paracercion melanotum (Selys, 1876)										**	
Pseudagrion microcephalum (Rambur, 1842)											
Pseudagrion pruinosum fraseri Schmidt, 1934											
Pseudagrion rubriceps rubriceps Selys, 1876											
PLATYCNEMIDIDAE											
Copera marginipes (Rambur, 1842)											
Onychargia atrocyana Selys, 1865											
Prodasineura autumnalis (Fraser, 1922)											

Pseudocopera ciliata (Selys, 1863)											
AESHNIDAE											
Anaciaeschna jaspidea (Burmeister, 1839)											
Anax guttatus (Burmeister, 1839)											
Anax parthenope julius (Brauer, 1865)											
Gynacantha japonica Bartenef, 1909			*								
Tetracanthagyna waterhousii McLachlan, 1898											
GOMPHIDAE											
Burmagomphus vermicularis (Martin, 1904)											
Ictinogomphus pertinax (Hagen in Selys, 1854)											
Lamelligomphus hainanensis (Chao, 1953)										**	
Paragomphus capricornis (Förster, 1914)										†	
Sinictinogomphus clavatus (Fabricius, 1775)											
MACROMIIDAE											
Epophthalmia elegans (Brauer, 1865)											
Macromia berlandi Lieftinck, 1941											
Macromia urania Ris, 1916											
CORDULIIDAE											
Idionyx victor Hämäläinen, 1991											
Macromidia ellenae Wilson, 1996			*								
LIBELLULIDAE											
Acisoma panorpoides Rambur, 1842											
Aethriamanta brevipennis brevipennis (Rambur, 1842)											
Brachydiplax chalybea flavovittata Ris, 1911											
Brachythemis contaminata (Fabricius, 1793)											

Crocothemis servilia servilia (Drury, 1770)											
Hydrobasileus croceus (Brauer, 1867)											
Lyriothemis elegantissima Selys, 1883											
Nannophya pygmaea Rambur, 1842			*								
Nannophyopsis clara (Needham, 1930)											
Neurothemis fulvia (Drury, 1773)											
Neurothemis tullia tullia (Drury, 1773)											
Onychothemis testacea testacea Laidlaw, 1902											
Orthetrum chrysis (Selys, 1891)											
Orthetrum glaucum (Brauer, 1865)											
Orthetrum luzonicum (Brauer, 1868)											
Orthetrum poecilops poecilops Ris, 1919											
Orthetrum pruinosum neglectum (Rambur, 1842)											
Orthetrum sabina sabina (Drury, 1770)											
Orthetrum triangulare triangulare (Selys, 1878)											
Palpopleura sexmaculata sexmaculata (Fabricius, 1787)											
Pantala flavescens (Fabricius, 1798)											
Potamarcha congener (Rambur, 1842)										†	
Pseudothemis zonata (Burmeister, 1839)											
Rhodothemis rufa (Rambur, 1842)											
Rhyothemis triangularis Kirby, 1889											
Rhyothemis variegata aria (Drury, 1773)											

Tholymis tillarga (Fabricius, 1798)											
Tramea virginia (Rambur, 1842)											
Trithemis aurora (Burmeister, 1839)											
Trithemis festiva (Rambur, 1842)											
Urothemis signata signata (Rambur, 1842)											
Zygonyx asahinai Matsuki and Saito, 1995											
Zygonyx iris insignis (Kirby, 1900)											
Zyxomma petiolatum Rambur, 1842											
No. of species recorded	8	5	35	33	23	20	8	14	17	43	26

PSL1 - Pat Sin Leng Site 1; PSL2 - Pat Sin Leng Site 2; LKM - Luk Keng Marsh; MTL - Ma Tso Lung; YSO - Yung Shue O; SW - Shuen Wan; LP - Lamma Pond; KMT - Kang Mun Tsui; LTNY - Lung Tsai Ng Yuen; TSR - Tan Shan River; NC - Nam Chung.

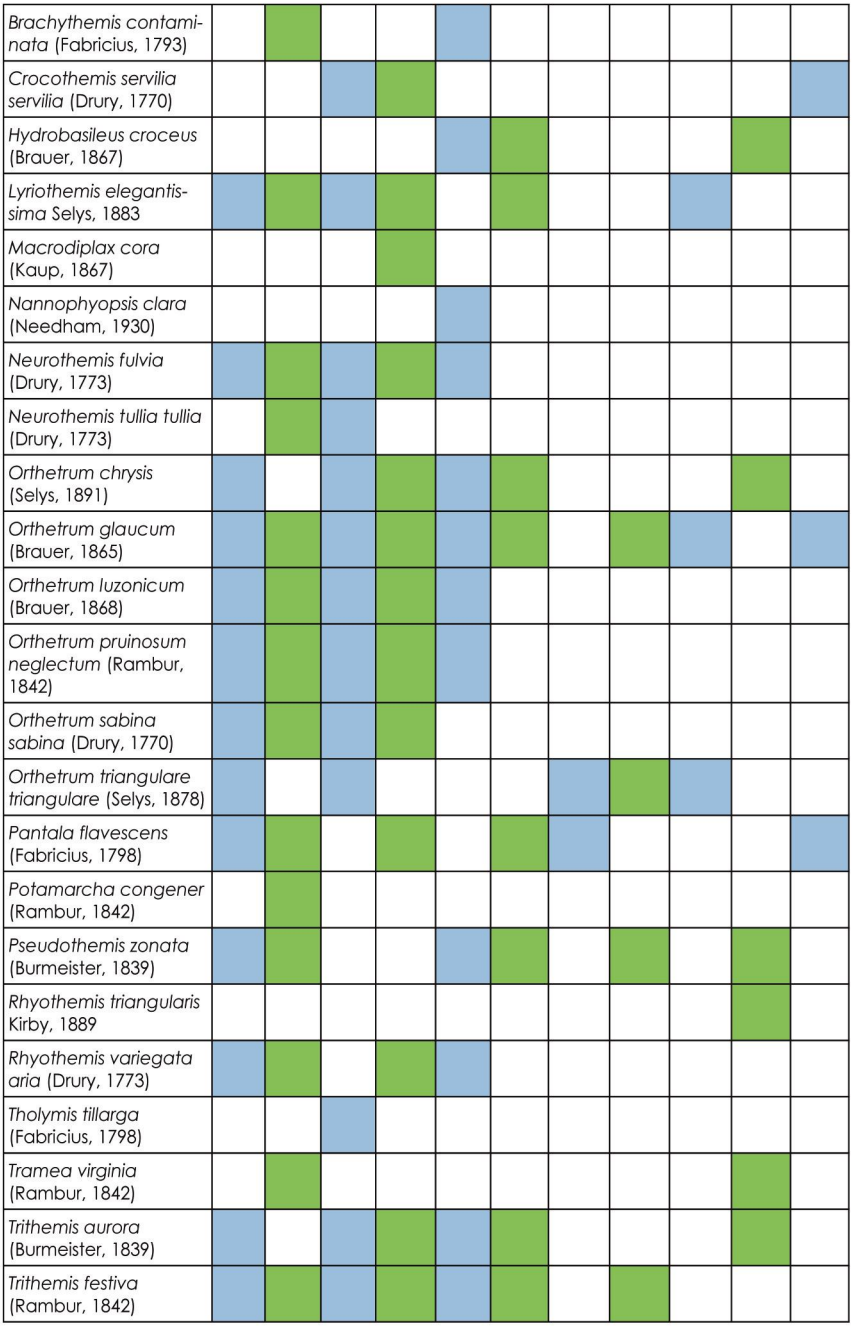
* Species recorded by Bergman Ng, 2016 (pers. comm.). ** Species recorded by Bergman Ng, 2017 (pers. comm.). † Species recorded by Ken So and students, 2017 (pers. comm.).

Appendix 1.1. Species recorded at sites 12-22.

Species/taxon	**Sites 12-22**										
	TTS	SLTB	WKT	SSS	ST	UTLR	KS	NTC	TMSS	TPK	SP
PHILOGANGIDAE											
Philoganga vetusta Ris, 1912	■	■	■					■	■		
CALOPTERYGIDAE											
Mnais mneme Ris, 1916		■	■			■		■	■	■	
Neurobasis chinensis chinensis (Linnaeus, 1758)	■			■	■	■					
CHLOROCYPHIDAE											
Rhinocypha perforata perforata (Percheron, 1835)	■	■	■	■	■	■	■	■	■	■	■
EUPHAEIDAE											
Euphaea decorata Hagen in Selys, 1853	■	■	■		■	■	■	■	■	■	■
MEGAPODAGRIONIDAE											
Agriomorpha fusca May, 1933							■	■	■	■	■
Rhipidolestes janetae Wilson, 1997									■		■
COENAGRIONIDAE											
Agriocnemis femina oryzae Lieftinck, 1962			■	■							
Agriocnemis pygmaea (Rambur, 1842)				■							
Ceriagrion auranticum ryukyuanum Asahina, 1967	■	■	■	■	■	■		■		■	
Pseudagrion microcephalum (Rambur, 1842)					■						
Pseudagrion pruinosum fraseri Schmidt, 1934		■	■	■							
Pseudagrion rubriceps rubriceps Selys, 1876	■			■	■						
PLATYCNEMIDIDAE											
Calicnemia sinensis Lieftinck, 1984								■		■	■
Coeliccia cyanomelas Ris, 1912		■	■			■	■	■	■	■	■
Copera marginipes (Rambur, 1842)	■	■	■	■	■	■			■	■	

Onychargia atrocyana Selys, 1865											
Prodasineura autumnalis (Fraser, 1922)											
Prodasineura croconota (Ris, 1916)											
Pseudocopera ciliata (Selys, 1863)											
PLATYSTICTIDAE											
Drepanosticta hongkongensis Wilson, 1997											
Protosticta beaumonti Wilson, 1997											
Protosticta taipokauensis Asahina & Dudgeon, 1987											
Sinosticta ogatai (Matsuki & Saito, 1996)											
AESHNIDAE											
Anax guttatus (Burmeister, 1839)											
Anax immaculifrons Rambur, 1842											
Anax parthenope julius (Brauer, 1865)											
Cephalaeschna klotsae Asahina, 1982								††			
Gynacantha japonica Bartenef, 1909			*								
Gynacantha subinterrupta Rambur, 1842											
Polycanthagyna erythromelas (McLachlan, 1896)											
Tetracanthagyna waterhousei McLachlan, 1898											
GOMPHIDAE											
Asiagomphus Hainanensis (Chao, 1953)											
Burmagomphus vermicularis (Martin, 1904)											
Fukienogomphus choifongae Wilson & Tam, 2006			†								
Gomphidia kelloggi Needham, 1930											
Heliogomphus scorpio (Ris, 1912)											

Ictinogomphus pertinax (Hagen in Selys, 1854)											
Lamelligomphus hainanensis (Chao, 1953)											
Leptogomphus hongkongensis Asahina, 1988											
Megalogomphus sommeri (Selys, 1854)											
Melligomphus guangdongensis (Chao, 1994)											
Ophiogomphus sinicus (Chao, 1954)		**									
Paragomphus capricornis (Förster, 1914)											
Sieboldius alexanderi Chao, 1955											
Sinictinogomphus clavatus (Fabricius, 1775)											
Stylogomphus chunliuae Chao, 1954											
CORDULEGASTERIDAE											
Anotogaster sp. cf *klossi*										+	
MACROMIIDAE											
Epophthalmia elegans (Brauer, 1865)											
Macromia berlandi Lieftinck, 1941											
Macromia katae Wilson, 1993											
Macromia urania Ris, 1916											
CORDULIIDAE											
Idionyx victor Hämäläinen, 1991											
Macromidia rapida Martin, 1906											
LIBELLULIDAE											
Acisoma panorpoides Rambur, 1842											
Aethriamanta brevipennis brevipennis (Rambur, 1842)											
Brachydiplax chalybea flavovittata Ris, 1911											


Brachythemis contaminata (Fabricius, 1793)
Crocothemis servilia servilia (Drury, 1770)
Hydrobasileus croceus (Brauer, 1867)
Lyriothemis elegantissima Selys, 1883
Macrodiplax cora (Kaup, 1867)
Nannophyopsis clara (Needham, 1930)
Neurothemis fulvia (Drury, 1773)
Neurothemis tullia tullia (Drury, 1773)
Orthetrum chrysis (Selys, 1891)
Orthetrum glaucum (Brauer, 1865)
Orthetrum luzonicum (Brauer, 1868)
Orthetrum pruinosum neglectum (Rambur, 1842)
Orthetrum sabina sabina (Drury, 1770)
Orthetrum triangulare triangulare (Selys, 1878)
Pantala flavescens (Fabricius, 1798)
Potamarcha congener (Rambur, 1842)
Pseudothemis zonata (Burmeister, 1839)
Rhyothemis triangularis Kirby, 1889
Rhyothemis variegata aria (Drury, 1773)
Tholymis tillarga (Fabricius, 1798)
Tramea virginia (Rambur, 1842)
Trithemis aurora (Burmeister, 1839)
Trithemis festiva (Rambur, 1842)

Urothemis signata signata (Rambur, 1842)											
Zygonyx asahinai Matsuki and Saito, 1995											
Zygonyx iris insignis (Kirby, 1900)											
Zyxomma petiolatum Rambur, 1842											
No. of species recorded	34	43	42	27	32	23	13	20	19	29	13

TTS - Tai Tong Stream; SLTB - Sha Lo Tung Basin; WKT - Wu Kau Tang; SSS - She Shan Stream; ST - Sham Tseng; UTLR - Upstream Tai Lam Reservoir; KS - Keung Shan; NTC - Ng Tung Chai; TMSS - Tai Mo Shan South; TPK - Tai Po Kau; SP - Sunset Peak. * Species recorded by Bergman Ng, 2016 (pers. comm.). ** Species recorded by Bergman Ng, 2017 (pers. comm.). † Species recorded by Bergman Ng, 2016 and 2017 (pers. comm.). †† Species recorded by Mahler Ka, 2016 (pers. comm.). + Species recorded by Tommy Hui, 2016.

Appendix 1.3. Species recorded at sites 23-33.

Species/taxon	**Sites 23-33**										
	STMK	KKSH	KP	NSW	YLC	HKWP	HT	MUP	TSH	HCS	DI
PHILOGANGIDAE											
Philoganga vetusta Ris, 1912											
CALOPTERYGIDAE											
Mnais mneme Ris, 1916											
Neurobasis chinensis chinensis (Linnaeus, 1758)											
CHLOROCYPHIDAE											
Rhinocypha perforata perforata (Percheron, 1835)											
EUPHAEIDAE											
Euphaea decorata Hagen in Selys, 1853											
LESTIDAE											
Lestes nodalis Selys, 1891											
MEGAPODAGRIONIDAE											
Agriomorpha fusca May, 1933											
COENAGRIONIDAE											
Aciagrion approximans (Selys, 1876)									+		
Agriocnemis femina oryzae Lieftinck, 1962											
Ceriagrion auranticum ryukyuanum Asahina, 1967											
Ischnura senegalensis (Rambur, 1842)											
Mortonagrion hirosei Asahina, 1972											
Paracercion melanotum (Selys, 1876)											
Pseudagrion microcephalum (Rambur, 1842)											
Pseudagrion pruinosum fraseri Schmidt, 1934											
Pseudagrion rubriceps rubriceps Selys, 1876											

PLATYCNEMIDIDAE											
Coeliccia cyanomelas Ris, 1912											
Copera marginipes (Rambur, 1842)											
Onychargia atrocyana Selys, 1865											
Prodasineura autumnalis (Fraser, 1922)											
Prodasineura croconota (Ris, 1916)											
Pseudocopera ciliata (Selys, 1863)											
AESHNIDAE											
Anax guttatus (Burmeister, 1839)											
Anax immaculifrons Rambur, 1842											
Anax parthenope julius (Brauer, 1865)											
GOMPHIDAE											
Anisogomphus koxingai Chao, 1954											
Asiagomphus hainanensis (Chao, 1953)											
Burmagomphus vermicularis (Martin, 1904)											
Gomphidia kelloggi Needham, 1930											
Heliogomphus scorpio (Ris, 1912)											
Ictinogomphus pertinax (Hagen in Selys, 1854)											
Labrogomphus torvus Needham, 1931							††				
Lamelligomphus hainanensis (Chao, 1953)											
Leptogomphus hongkongensis Asahina, 1988											
Megalogomphus sommeri (Selys, 1854)											
Melligomphus guangdongensis (Chao, 1994)											
Ophiogomphus sinicus (Chao, 1954)											

Paragomphus capricornis (Förster, 1914)											
Sieboldius alexanderi Chao, 1955											
Sinictinogomphus clavatus (Fabricius, 1775)											
MACROMIIDAE											
Epophthalmia elegans (Brauer, 1865)											
Macromia katae Wilson, 1993											
CORDULIIDAE											
Idionyx victor Hämäläinen, 1991											
Macromidia ellenae Wilson, 1996							**				
Macromidia rapida Martin, 1906											
LIBELLULIDAE											
Acisoma panorpoides Rambur, 1842											
Aethriamanta brevipennis brevipennis (Rambur, 1842)											
Brachydiplax chalybea flavovittata Ris, 1911											
Brachythemis contaminata (Fabricius, 1793)											
Crocothemis servilia servilia (Drury, 1770)											
Diplacodes trivialis (Rambur, 1842)											
Hydrobasileus croceus (Brauer, 1867)											
Lyriothemis elegantissima Selys, 1883											
Macrodiplax cora (Kaup, 1867)											
Nannophya pygmaea Rambur, 1842											
Nannophyopsis clara (Needham, 1930)							**				
Neurothemis fulvia (Drury, 1773)											
Neurothemis tullia tullia (Drury, 1773)											

Orthetrum chrysis (Selys, 1891)											
Orthetrum glaucum (Brauer, 1865)											
Orthetrum luzonicum (Brauer, 1868)											
Orthetrum poecilops poecilops Ris, 1919											
Orthetrum pruinosum neglectum (Rambur, 1842)											
Orthetrum sabina sabina (Drury, 1770)											
Orthetrum triangulare triangulare (Selys, 1878)											
Palpopleura sexmaculata sexmaculata (Fabricius, 1787)											
Pantala flavescens (Fabricius, 1798)											
Potamarcha congener (Rambur, 1842)						**					
Pseudothemis zonata (Burmeister, 1839)											
Rhodothemis rufa (Rambur, 1842)											
Rhyothemis triangularis Kirby, 1889											
Rhyothemis variegata aria (Drury, 1773)											
Tholymis tillarga (Fabricius, 1798)											
Tramea virginia (Rambur, 1842)											
Trithemis aurora (Burmeister, 1839)											
Trithemis festiva (Rambur, 1842)											
Trithemis pallidinervis (Kirby, 1889)						*					
Urothemis signata signata (Rambur, 1842)											
Zygonyx iris insignis (Kirby, 1900)											
Zyxomma petiolatum Rambur, 1842		†				**					
No. of species recorded	8	33	29	6	23	24	34	29	26	11	5

STMK - Sheung Tsat Muk Kiu; KKSH - Kai Kuk Shue Ha; KP - Kuk Po; NSW - Nam Sang Wai; YLC - Yuen Leng Chai; HKWP - Hong Kong Wetland Park; HT - Hok Tau; MUP - Man Uk Pin; TSH - Tai Shui Hang; HCS - Hang Cho Stream; DI - Double Island. * Species recorded by Edmond Sham, 2016 (pers. comm.). ** Species recorded by Bergman Ng, 2017 (pers. comm.). † Species recorded by Ken So and students, 2017. †† Species recorded by Bill Ho, 2017 (pers. comm.). + Species recorded by Bergman Ng, 2016 and 2017 (pers. comm.).

Appendix 2. Hong Kong dragonfly species conservation importance assessment metric.

Scoring allocation for each species

(i) Percentage of world range in southeast China

	Score
Estimated ≥50% of world range in southeast China	10
Endemic to southeast China	20
Estimated ≥50% of known world range in Hong Kong	30

(ii) IUCN Red Listing

	Score
Data Deficient	5
Near Threatened	5
Vulnerable	10
Endangered	20

(iii) Localisation - 3 or fewer Hong Kong sites with known breeding populations

	Score
3 sites	10
2 sites	15
1 site	25

(iv) Priority species (Moore, 1997)

	Score
Taxonomically isolated species	15
Species in monotypic genus restricted to one country	15
Species with unusual biology	15

(v) Apparent population decline trends in Hong Kong, 1997 to 2017

	Score
Abundant/very common (1995-2011) >>> Scattered (present study)	3
Common/widespread (1995-2011) >>> Sparse (present study)	5

(vi) Species richness

	Score
Any species not falling under (i) to (v)	1

"Southeast China" refers to the Hong Kong and Macau Special Administrative Regions and the provinces of Guizhou, Hunan, Jiangxi, Zhejiang, Guangxi, Guangdong, Fujian and Hainan. Species that are presumed extinct, vagrant or of uncertain status in Hong Kong are excluded. All other Hong Kong species (as listed in Reels 2019), come under category (vi) of the metric and score 1 point each.

Species in categories (i) to (v)

Species	Points per category					Total score
	(i)	(ii)	(iii)	(iv)	(v)	
Philoganga vetusta	10			15		25
Mnais mneme	10					10
Euphaea decorata	10					10
Lestes nodalis			15			15
Agriomorpha fusca	10				3	13
Rhipidolestes janetae	30		10	15		55
Aciagrion approximans			25			25
Agriocnemis femina					3	3
Agriocnemis lacteola			25			25
Agriocnemis pygmaea					5	5
Ischnura senegalensis					3	3
Mortonagrion hirosei		5		15		20
Paracercion calamorum					5	5
Calicnemia sinensis	20				5	25
Onychargia atrocyana				15		15
Coeliccia cyanomelas	10					10
Prodasineura croconota	10					10
Drepanosticta hongkongensis	20					20
Protosticta beaumonti	20					20
Protosticta taipokauensis	10				5	15
Sinosticta ogatai	30			15		45
Anaciaeschna jaspidea					5	5
Anax guttatus					3	3
Anax immaculifrons					5	5
Cephalaeschna klotsae	10	5	25			40
Gynacantha japonica					5	5
Planaeschna skiaperipola	20		25			45
Anisogomphus koxingai	10					10
Asiagomphus hainanensis	20					20
Burmagomphus vermicularis	10					10
Fukienogomphus choifongae	30		25			55
Gomphidia kelloggi	20	20	15			55
Heliogomphus retroflexus	10					10
Heliogomphus scorpio	10					10
Labrogomphus torvus	10					10

Species	Points per category					Total score
	(i)	(ii)	(iii)	(iv)	(v)	
Lamelligomphus hainanensis	20					20
Leptogomphus hongkongensis	30					30
Megalogomphus sommeri	10					10
Melligomphus guangdongensis	20				5	25
Ophiogomphus sinicus	20	5			5	30
Sieboldius alexanderi	10	5				15
Stylogomphus chunliuae	10				5	15
Stylurus annulatus	10					10
Anotogaster sp. cf *klossi*			25			25
Macromia berlandi	10					10
Macromia katae	10	10	10			30
Macromia urania	10					10
Idionyx claudia	10		25			35
Idionyx victor	10					10
Macromidia ellenae	20					20
Brachythemis contaminata					3	3
Crocothemis servilia					3	3
Diplacodes trivialis					5	5
Nannophya pygmaea					5	5
Onychothemis testacea				15		15
Orthetrum poecilops	10	10		15		35
Palpopleura sexmaculata					5	5
Zygonyx asahinai	10					10

Appendix 3. Selected Hong Kong dragonfly species.

***Acisoma panorpoides* at Luk Keng marsh, April 2016. A widespread marsh species, recorded at 10 sites.**

***Brachydiplax chalybea* at Kai Kuk Shue Ha, April 2016. A common pond species, recorded at 16 sites.**

***Coeliccia cyanomelas* at Ng Tung Chai, June 2016. A common forest species, recorded at 10 sites.**

Ischnura senegalensis **at Luk Keng marsh, April 2016. This globally widespread species can be abundant at managed fish ponds in Hong Kong but was only recorded at six sites in the present study.**

Lyriothemis elegantissima **at Kai Kuk Shue Ha, April 2016. Commonly found in woodland beside marshy habitat, in which it breeds. Recorded at 19 sites.**

Sinosticta ogatai **female ovipositing at Ng Tung Chai, June 2016. This unusual platystictid was found at just three upland forest sites.**

***Mnais mneme* at Sha Lo Tung, April 2016. A species with a short flight season from April to June. Recorded at 11 sites.**

***Nannophya pygmaea* at Sheung Tsat Muk Kiu, April 2016. A species that appears to have declined in Hong Kong in recent years. Recorded at two sites.**

***Pseudocopera ciliata* tandem at Luk Keng, April 2016. A widespread platycnemidid, recorded at 13 sites.**

***Potamarcha congener* at Sha Lo Tung, May 2017. A scattered species in Hong Kong, recorded at four sites.**

***Rhipidolestes janetae* at Tai Mo Shan South, May 2016. A sparsely distributed species of upland streams and seepages, recorded at two sites.**

***Rhodothemis rufa* at Luk Keng (photographed in 2010). A widespread pond species, recorded at eight sites.**

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