



基于昆虫证据推断死亡时间的研究进展*

吴世豪^{1**} 王继芬^{1***} 白海涛² 张震¹ 鲁朋武³

(1. 中国人民公安大学侦查学院, 北京 100038; 2. 山西省太原市公安局刑侦支队, 太原 030000;

3. 中国人民公安大学公安管理学院, 北京 100038)

摘要 死亡时间的推断是法医昆虫学鉴定中首先要解决的问题。尸体上昆虫的生长发育及群落演替具有一定的规律, 这能够用于推断尸体死亡时间。本文从昆虫证据的收集及种属鉴定、昆虫的发育与群落演替、影响昆虫证据推断死亡时间的因素以及法医昆虫学发展面临的挑战等几个方面展开综述, 并对我国法医昆虫学的应用进展做了简要展望。

关键词 法医昆虫学; 死后间隔时间; 嗜尸性昆虫; 昆虫群落演替; 发育模型

Progress in research on the estimating time of death based on insect evidence

WU Shi-Hao^{1**} WANG Ji-Fen^{1***} BAI Hai-Tao² ZHANG Zhen¹ LU Peng-Wu³

(1. School of Investigation, People's Public Security University of China, Beijing 100038, China;

2. Criminal Investigation Detachment of Taiyuan Public Security Bureau in Shanxi Province, Taiyuan 030000, China;

3. School of Public Security Administration, People's Public Security University of China, Beijing 100038, China)

Abstract Estimating of time of death is the first problem to be solved in forensic entomology. The development and faunal succession of insects on cadavers has certain rules, which can be used to estimate the time of death. This paper reviews the collection and identification of insects commonly used to estimate the time of death, progress in research on insect development and succession, factors affecting the estimation of time of death and challenges in forensic entomology. In addition, future prospects for progressing the application of forensic entomology in China are presented.

Key words forensic entomology; postmortem interval; sarcophagous insects; insect faunal succession; developmental model

死亡时间也称死后间隔时间 (Postmortem interval, PMI), 是法医学研究的核心问题之一 (吕宙和万立华, 2016)。根据尸体状况、现场环境及案件相关信息等, 人们有多种方法推断死亡时间。法医昆虫学家对尸体上出现的昆虫进行研究, 利用其生长发育及演替规律进行死亡时间的推断。

法医昆虫学 (Forensic entomology) 是应用昆虫及其他自然科学的理论与技术, 研究并解决司法实践中有关昆虫问题的一门科学, 其研究对

象为生活在人类或动物尸体上的昆虫及其它节肢动物 (Goff, 2000; 胡萃, 2000)。昆虫证据除了能够用于推断死亡时间, 还有助于判断死者生前是否受过创伤或服用过毒物毒品, 尸体是否曾被转移等 (Mona *et al.*, 2019)。2020年5月中国司法部通过《法医类司法鉴定执业分类规定》, 正式将昆虫证据认可为推断死亡时间的可靠方法, 这对我国的法医昆虫学而言是一个重大的突破。本文对近年来国内外法医昆虫学的相关研究进行总结, 阐述了昆虫证据的收集指南、种

*资助项目 Supported projects: 中央高校基本科研业务费专项资金 (2021JKF208)

**第一作者 First author, E-mail: 1449708607@qq.com

***通讯作者 Corresponding author, E-mail: wangjifen58@126.com

收稿日期 Received: 2021-11-16; 接受日期 Accepted: 2022-04-15

属鉴定的方法以及影响昆虫发育及演替的因素,并对我国法医昆虫学在研究与应用中面临的挑战进行了分析。

1 昆虫证据的收集与鉴定

1.1 昆虫证据的收集

在我国,死亡现场的昆虫证据通常由公安机关的刑事侦查人员或法医进行收集,法医昆虫学工作者主要在研究机构中从事相关研究工作而很少直接参与现场勘查。然而死亡现场的昆虫种类多且易变换,并且在我国采集昆虫证据的标准操作方法还未得到全面应用(马孟云等, 2016),非专业人员在收集时难以做到准确全面,从而严重影响昆虫证据的有效性。在国外的一起案例中, Matuszewski 和 Anna (2019) 比较了执法部门的现场勘查人员和法医昆虫学家在收集昆虫证据时存在的差异,以此来探究昆虫证据收集的准确性对 PMI 推断准确性的影响。结果显示,由执法部门人员收集的昆虫样本明显缺乏多样

性,基于此仅能对最短死亡时间即尸体至少存在的时间(Minimum postmortem interval, PMImin)做出相关的判断。而通过分析昆虫学家收集的昆虫证据除了能推断出最短死亡时间,还能推断出具有重要意义的最大死亡时间(Maximum PMI)。由此可见,采用标准化的昆虫证据收集方法是很有必要的。马孟云等(2016)学者对此进行了探讨,以期规范法医昆虫学现场操作标准及程序。

表 1 简要列出了收集昆虫证据的指南,指明了处于不同腐败阶段的尸体上昆虫证据的类型以及存在部位。尽管尸体上的昆虫种类及数量繁多,且同种昆虫会处于不同的发育阶段,但在收集时仅有一小部分的昆虫证据是必需的。法医昆虫学家通常选择最早进行群落演替的昆虫中处于最高发育阶段的个体进行研究,即使在复杂的情况下选用的物种也通常不超过 3 个,但在现场进行收集时难以准确判断哪些为必需的昆虫证据,因此要收集尽可能多的昆虫证据,并采用合适的方法进行处理(Bajerlein *et al.*, 2018)。

表 1 死亡现场昆虫证据收集指南
Table 1 Guidelines for collecting insect evidence at the scene of death

尸体状态 State of a cadaver	昆虫证据 Insect evidence	
	证据类型 Type of evidence	证据位置 Position of evidence
相对新鲜 Relatively fresh	蝇类的卵和幼虫 Eggs and larvae of flies	自然孔口(尤其是头部), 伤口 Natural orifices (particularly of the head), wounds
有腐烂迹象(肿胀等) Signs of putrefaction (bloating, etc.)	蝇类幼虫和蛹 Larvae and pupae of flies	自然孔口, 伤口, 尸体与地面分界处 Natural orifices, wounds, interface cadaver/ground
积极腐败期(大量幼虫、尸臭等) Signs of active decay (massive insect larvae, stench of decay, etc.)	蝇类幼虫和蛹, 甲虫类成虫和幼虫 Larvae and pupae of flies, adult and larvae of beetles	幼虫群, 衣服和尸体表面, 尸体附近的表层土或地板 Larval masses, clothes and cadaver surface, the soil or the floor in the vicinity of a cadaver
高度腐败期(骨骼暴露、皮肤变黑等) Signs of advanced decay (exposed bones, skin blackening, etc.)	蝇类幼虫和蛹, 甲虫类成虫和幼虫 Larvae and pupae of flies, adult and larvae of beetles	幼虫群, 尸体表面, 尸体附近的表层土或地板, 衣服的口袋和褶皱 Larval masses, cadaver surface, the soil or the floor in the vicinity of a cadaver, pockets and creases of clothes
大规模腐败或木乃伊化 Massive putrefaction or mummification	所有类型的昆虫及其他节肢动物 All types of insect evidence	自然孔口, 伤口, 衣服和尸体表面, 尸体附近的表层土或地板 Natural orifices, wounds, clothes and cadaver surface, the soil or the floor in the vicinity of a cadaver

1.2 昆虫证据的物种鉴定

在收集昆虫证据后需要对昆虫的物种进行鉴定, 准确鉴定昆虫的物种后, 才能根据其演替及发育规律推断死亡时间, 这是分析昆虫证据的第一步也是极为关键的一步 (Harvey *et al.*, 2008)。几十年来, 昆虫学家对我国的蝇类及甲虫进行了全面和系统的研究 (郭鄂, 1952; 范滋德, 1957a, 1957b; 甘运兴, 1958; 薛万琦, 1976; 张孟余, 1982; 张生芳和刘永平, 1985; 罗淑德和 Halstead, 1989; 陈禄仕, 2004; 常云峰等, 2006; Xue *et al.*, 2011), 而后陈禄仕 (2013) 在此基础上对尸食性蝇类进行了汇总, 记述了这些昆虫的基本形态特征、分布及其相应的属、种检索表。彭倩宜等 (2009) 对常见鞘翅目嗜尸性甲虫进行了汇总, 简述了这些甲虫在尸体上的演替及食性, 为尸体上昆虫的种属鉴定建立了一定的基础。

在进行昆虫的物种鉴定时, 法医昆虫学领域最初是通过昆虫的形态学分类特征进行分析识别的, 这种方法发展至今已得到了大量应用, 一直是嗜尸性昆虫种属鉴定的“金标准” (蔡继峰, 2011)。但该方法要求检验人员具备专业系统的昆虫分类学知识, 并且在实践中存在一些不适用的情形, 如有些蝇类的幼虫需要等到成虫羽化后才能通过形态特征进行鉴定 (冉渊等, 2021)。为了提高识别的准确性以及拓宽适用范围, Sperling 等 (1994) 最早将分子生物学技术引入到嗜尸性蝇类的种属鉴定中, 证实了 DNA 序列分析方法的有效性。经过几十年的发展, DNA 测序技术逐渐成熟。得益于此, 我国的法医昆虫学家已对具有重要法医学价值的昆虫进行了一系列的研究, 其中包括丽蝇科、麻蝇科、家蝇科和一些鞘翅目昆虫。这些昆虫的线粒体和细胞核 DNA 标记等已经得到广泛研究 (陈庆等, 2009; Guo *et al.*, 2010, 2011a, 2012, 2014; Liu *et al.*, 2011; Su *et al.*, 2013; Meng *et al.*, 2017; 翟仙敦等, 2017; Chen *et al.*, 2018; Ren, 2018; 卓萃等, 2020)。如卓萃等 (2020) 对我国福建省常见嗜尸性蝇类展开的实验发现线粒体 CO I 及 16SrDNA 这 2 种基因片段序列均能够实现不同

蝇种间较为准确的种属鉴别。在进行分子鉴定时需要注意, 单独的 DNA 片段并不能准确推断昆虫的物种, 多片段结合分析才能提供更为可靠的结果。除了对单独的基因片段进行分析外, 一些研究人员 (Shang *et al.*, 2019; Zhang *et al.*, 2019c) 还对昆虫的线粒体基因组进行了总体研究。如 Zhang 等 (2019c) 对 *Chrysomya nigripes* (双翅目丽蝇科) 进行了全线粒体基因组测序, 结果显示该方法能够提供更加有效的信息来实现该蝇种与其他物种的区分。

除了上述方法, 研究人员发现昆虫表皮中的碳氢化合物 (Cuticular hydrocarbons, CHCs) 也能够用于昆虫的分类鉴定。早在 20 世纪 70 年代初已有相关的报道 (Jackson and Baker, 1970; Tartivita and Jackson, 1970), 而后 Carlson 等 (1978) 及 Carlson 和 Service (1979) 对 CHCs 的组成及种间差异进行了深入研究, 真正意义上开启了昆虫化学分类学的研究先河。在法医昆虫学领域, Byrne 等 (1995) 通过分析表皮碳氢化合物, 将来自 3 个地理种群的伏蝇 *Phormia regina* (Meigen) 区分开来, 由此证明 CHCs 在判断尸体是否被转移方面具有潜在的应用价值。Ye 等 (2007) 对巨尾阿丽蝇 *Aldrichina grahami*、大头金蝇 *Chrysomya megacephala* 及丝光绿蝇 *Lucilia sericata* 等 6 种嗜尸性苍蝇的蛹壳中的表皮碳氢化合物进行了分析, 成功地将这 6 种苍蝇区分开来。Moore 等 (2014) 采用气质联用和主成分分析法对丝光绿蝇、红头丽蝇 *Calliphora vicina* 和反吐丽蝇 *Calliphora vomitoria* 的 1 龄幼虫的表皮碳氢化合物进行了分析, 结果显示不同物种之间存在明显差异且能够用于区分。基于表皮碳氢化合物的昆虫化学分类学已成为昆虫分类的一个重要的辅助工具, 在法医昆虫学领域发挥出其独有的价值 (李群臣等, 2019)。

2 昆虫的个体发育

对昆虫生长发育规律的研究能够用于推断尸体的死亡时间, 在我国这项研究开始于 20 世纪 90 年代 (马玉堃等, 1998)。法医昆虫学家推断昆虫首次入侵尸体后生长发育所经历的时间,

这一时间与真实死亡时间相比要略短一些, 可用作最短死亡时间 (Jens *et al.*, 2007)。由于难以确定成虫首次入侵尸体时的年龄, 所以法医昆虫学家的研究对象通常为尸体上的幼虫 (Amendt *et al.*, 2011)。在推断幼虫年龄时, 我国的学者已对幼虫的体长变化进行了大量的研究 (表 2)。但李艳宇 (2007) 指出, 蝇类幼虫的体长容易受人为因素影响, 并且幼虫在 3 龄的离食期体长会有不同程度的缩短, 容易与正在生长发育的幼虫相混淆。因此为了实现更加准确的昆虫虫龄推断, 李艳宇 (2007) 对丝光绿蝇幼虫形态特征 (如幼虫的头咽骨骼和前后气门等) 的变化进行了研究, 发现幼虫头咽骨形态及各部位长度及幼虫体表棘刺的结构和颜色等随时间的变化都有一定的规律。同样的, 赵博等 (2009) 研究发现丝光绿蝇幼虫后气门平均光密度、咽骨骨化面积及平均光密度这 3 项指标是推断幼虫日龄较理想的指标, 王玲等 (2008) 研究发现肥须亚麻蝇 *Parasarcophaga crassipalpis* 咽骨的平均光密度及骨化面积是幼虫日龄最理想的判断指标。总的来说, 为了准确推断昆虫的虫龄, 我国的学者已对昆虫体长及形态特征等的变化展开大量研究, 以深入了解各种昆虫的发育规律。

需要注意, 在不同生态地理环境中昆虫的生长发育情况存在差异, 因此法医昆虫学者需对不同地区昆虫的发育情况进行研究, 在推断死亡时间时也需要依据最合适的昆虫发育数据进行推断 (Jens *et al.*, 2007; Richards, 2008; Owings, 2014)。而即使在同一地区, 在不同的实验条件和操作方法下得到的发育数据也有所不同, 这是因为昆虫的发育会受到多种因素的影响, 本文的第 5 部分对此进行了详细论述。在这些影响条件中, 温度对幼虫的发育起着至关重要的作用, 因为昆虫是变温动物, 其生长发育主要受温度控制 (Guo *et al.*, 2010)。因此在研究昆虫发育规律时, 法医昆虫学者会对温度条件进行严格的记录与控制。

Matuszewski (2021) 对世界范围内嗜尸性昆虫发育规律的研究进展进行了归纳, 指出尽管丝光绿蝇和红头丽蝇等常见蝇种已有多个发育数据集, 但仍有一些经常入侵尸体的重要昆虫尚未得到研究 (如叉叶绿蝇 *Lucilia caesar* 和青蓝郭公虫 *Necrobia violacea*) 或研究较少 (如脂酪蝇 *Stearibia nigriceps*、黄角尸葬甲 *Necrodes littoralis*、短角露尾甲 *Omosita colon* 和赤足郭公虫 *Necrobia rufipes*)。表 2 归纳了我国法医昆虫

表 2 我国嗜尸性昆虫的分布及发育温度

Table 2 Distribution and development temperature of sarcophagous insects in China

目 Order	种 Species	地区 Regions	温度 (°C) Temperatures (°C)	参考文献 References
双翅目 Diptera	棕尾别麻蝇 <i>Boettcherisca peregrina</i>	浙江杭州 Hangzhou, Zhejiang	16, 20, 24, 28, 32	王江峰, 1999
		广东广州 Guangzhou, Guangdong	15, 20, 25, 30, 35	汪海洋等, 2010
		江苏苏州 Suzhou, Jiangsu	16, 19, 22, 25, 28, 31, 34	Wang <i>et al.</i> , 2017c
		湖南长沙 Changsha, Hunan	15, 25, 35	Shang <i>et al.</i> , 2020
	亮绿蝇 <i>Lucilia illustris</i>	江苏苏州 Suzhou, Jiangsu	15, 20, 25, 30, 35	Wang <i>et al.</i> , 2016
		江苏苏州 Suzhou, Jiangsu	20, 25, 30	Wang <i>et al.</i> , 2018
	格氏丽蝇 <i>Calliphora grahami</i>	浙江杭州 Hangzhou, Zhejiang	12, 15, 18, 21, 24, 27, 30	马玉堃等, 1998
		浙江杭州 Hangzhou, Zhejiang	12, 16, 20, 24, 28	王江峰, 1999
		河北石家庄 Shijiazhuang, Hebei	16, 20, 24, 28, 32	赵博等, 2010
		江苏苏州 Suzhou, Jiangsu	16, 19, 22, 25, 28, 31, 34	Wang <i>et al.</i> , 2018c
		湖南长沙 Changsha, Hunan	15, 22, 27	Liu <i>et al.</i> , 2021
		湖南长沙 Changsha, Hunan	恒温 Constant temperature (8, 12, 16), 变温 Fluctuating temperature (6-12, 10-16, 14-20)	Chen <i>et al.</i> , 2019

续表 2 (Table 2 continued)

目 Order	种 Species	地区 Regions	温度 (°C) Temperatures (°C)	参考文献 References
双翅目 Diptera	大头金蝇 <i>Chrysomya megacephala</i>	浙江杭州 Hangzhou, Zhejiang	18, 21, 24, 27, 30, 33	马玉堃等, 1998
		浙江杭州 Hangzhou, Zhejiang	16, 20, 24, 28, 32	王江峰, 1999
		河北石家庄 Shijiazhuang, Hebei	16, 20, 24, 28, 32	赵博等, 2010
		重庆 Chongqing	16, 19, 22, 25, 28, 31, 34	Yang <i>et al.</i> , 2016
		江苏苏州 Suzhou, Jiangsu	16, 19, 22, 25, 28, 31, 34	Zhang <i>et al.</i> , 2018
	酱亚麻蝇 <i>Sarcophaga dux</i>	湖南长沙 Changsha, Hunan	16, 19, 22, 25, 28, 31, 34	Zhang <i>et al.</i> , 2020
	瘦叶带绿蝇 <i>Hemipyrellia ligurriens</i>	重庆 Chongqing	16, 19, 22, 25, 28, 31, 34	Yang <i>et al.</i> , 2015
	野亚麻蝇 <i>Parasarcophaga similis</i>	江苏苏州 Suzhou, Jiangsu	16, 19, 22, 25, 28, 31, 34	Yang <i>et al.</i> , 2017
	肥躯金蝇 <i>Chrysomya pinguis</i>	江苏苏州 Suzhou, Jiangsu	16, 19, 22, 25, 28, 31, 34	Zhang <i>et al.</i> , 2019b
	绯颜裸金蝇 <i>Chrysomya rufifacies</i>	广东广州 Guangzhou, Guangdong	20, 24, 28, 32	Ma <i>et al.</i> , 2015
		江苏苏州 Suzhou, Jiangsu	16, 19, 22, 25, 28, 31, 34	Hu <i>et al.</i> , 2019
	角喙栓蚤蝇 <i>Dohrniphora cornuta</i>	辽宁沈阳 Shenyang, Liaoning	15, 18, 21, 24, 27, 30, 33, 36	Feng <i>et al.</i> , 2021
	光亮扁角水虻 <i>Hermetia illucens</i>	广东广州 Guangzhou, Guangdong	20, 24, 28, 32	Li <i>et al.</i> , 2016a
	厚环黑蝇 <i>Hydrotaea spinigera</i>	江苏苏州 Suzhou, Jiangsu	16, 19, 22, 25, 28, 31, 34	Wang <i>et al.</i> , 2021
	铜绿蝇 <i>Lucilia cuprina</i>	河北石家庄 Shijiazhuang, Hebei	16, 20, 24, 28, 32	王贺等, 2008
	丝光绿蝇 <i>Lucilia sericata</i>	浙江杭州 Hangzhou, Zhejiang	18, 21, 24, 27, 30, 33	马玉堃等, 1998
		浙江杭州 Hangzhou, Zhejiang	16, 20, 24, 28, 32	Wang, 1999
		河北石家庄 Shijiazhuang, Hebei	16, 20, 24, 28, 32	李艳宇, 2007
		江苏苏州 Suzhou, Jiangsu	16, 19, 22, 25, 28, 31, 34	Wang <i>et al.</i> , 2020a
		广东广州 Guangzhou, Guangdong	20, 24, 28, 32	Li <i>et al.</i> , 2016b
	蛆症异蚤蝇 <i>Megaselia scalaris</i>	辽宁沈阳 Shenyang, Liaoning	18, 21, 24, 27, 30, 33, 36	Feng and Liu, 2014
	东亚异蚤蝇 <i>Megaselia spiracularis</i>	辽宁沈阳 Shenyang, Liaoning	21, 24, 27, 30, 33, 36	Feng and Liu, 2013
		江苏苏州 Suzhou, Jiangsu	16, 19, 22, 25, 28, 31, 34	Wang <i>et al.</i> , 2020d
	家蝇 <i>Musca domestica</i>	浙江杭州 Hangzhou, Zhejiang	16, 20, 24, 28	Wang, 1999
		江苏苏州 Suzhou, Jiangsu	16, 19, 22, 25, 28, 31, 34	Wang <i>et al.</i> , 2018b

续表 2 (Table 2 continued)

目 Order	种 Species	地区 Regions	温度 (°C) Temperatures (°C)	参考文献 References
	厩腐蝇 <i>Muscina stabulans</i>	江苏苏州 Suzhou, Jiangsu	16, 19, 22, 25, 28, 31, 34	Wang <i>et al.</i> , 2019b
	肥须亚麻蝇 <i>Parasarcophaga crassipalpis</i>	浙江杭州 Hangzhou, Zhejiang	18, 21, 24, 27, 30, 33	马玉堃等, 1998
		河北石家庄 Shijiazhuang, Hebei	16, 20, 24, 28, 32	Wang <i>et al.</i> , 2008
鞘翅目 Coleoptera	大隐翅虫 <i>Creophilus maxillosus</i>	江苏苏州 Suzhou, Jiangsu	20, 25, 30	Wang <i>et al.</i> , 2017d
	赤足郭公虫 <i>Necrobia rufipes</i>	江苏苏州 Suzhou, Jiangsu	22, 25, 28, 31, 34, 36	Hu <i>et al.</i> , 2020b
	短角露尾甲 <i>Omosita colon</i>	江苏苏州 Suzhou, Jiangsu	16, 19, 22, 25, 28, 31	Wang <i>et al.</i> , 2020c
膜翅目 Hymenoptera	丽蝇蛹集金小蜂 <i>Nasonia vitripennis</i>	江苏苏州 Suzhou, Jiangsu	16, 19, 22, 25, 28, 31, 34	Zhang <i>et al.</i> , 2019a

学者在该领域的研究现状。由表 2 及相关文献可知,对于某一特定物种的昆虫,研究人员在不同地区以及不同的温度条件下开展了实验,得到的数据之间存在明显差异。

3 昆虫的群落演替

人死后组织蛋白质会因腐败细菌的作用而发生分解,这一过程被称为尸体腐败。处于不同腐败阶段的尸体产生的化学信息物质有一定的差异,因此侵殖尸体的昆虫类群和数量会随着时间的推移发生变化(吕宙和万立华, 2016),这种昆虫活动被称为昆虫群落演替(Faunal succession of insects)。嗜尸性蝇类的群落演替规律会受气候、环境、尸体死亡原因和时间等多重因素的影响(叶鲁思等, 2010),但当自然环境保持相对稳定时,在同一生态地理环境内这种规律是相对稳定且可预测的(武红艳等, 2017)。比如在我国广东地区,当尸体处于新鲜期时丽蝇科的绿蝇属、金蝇属和丽蝇属较为常见,肿胀期时蚤蝇科、埋葬甲科和皮蠹科等开始出现,积极腐败期时黑蝇属和齿股蝇属等较为常见,而当尸体高度腐败时大量的蝇蛆开始化蛹,皮蠹科和露尾甲科常常开始产卵(任立品等, 2021)。

对于法医昆虫学研究人员而言,研究尸体的

腐败过程以及昆虫的群落演替主要有以下几个原因。首先,这些研究能够全面把握尸体上出现的各种昆虫,获知不同物种嗜尸性昆虫的生存环境和地理分布,这为法医昆虫学的进一步研究建立了基础。如杨利军(2017)在苏州开展的研究发现大头金蝇、丝光绿蝇和绯颜裸金蝇首先到达尸体,银眉黑蝇 *Ophyra leucostoma* 侵袭的时间则稍晚一些,随后甲虫类嗜尸性昆虫到达,成为尸体腐败后期及白骨化期的优势种。王江峰等(2008)研究发现在广东中山地区,大头金蝇与绯颜裸金蝇在尸体的腐败早期占据优势,到腐败中期则逐渐被厚环黑蝇所取代。嗜尸性昆虫在尸体上的演替规律存在区域性差异,在将其用作昆虫证据时需要根据当地的实际情况做出判断。

其次,对昆虫演替规律的研究为死亡时间的推断提供了相关数据,尤其对于死亡时间较长的尸体。当死亡已发生一周以上时,无法通过蝇蛆的生长发育历期推算死亡时间,但此时仍可借助嗜尸性昆虫的群落演替规律进行推断(吕宙等, 2015)。如对于木乃伊化的尸体,蝇类已经完成了从卵到成虫的发育,此时难以通过其发育规律来推断死亡时间,而通过研究皮蠹科(白腹皮蠹 *Dermestes maculatus* Degeer)等较晚侵殖尸体的昆虫在对应环境下的演替规律,则能较为准确地

推断出死亡时间 (Wang *et al.*, 2019a)。在进行昆虫演替研究时, 需要观察并记录昆虫的出现前期 (Pre-appearance interval, PAI) 即从死亡发生到昆虫出现在尸体上所经过的时间和存在时间即从昆虫在尸体上首次出现到检验所经过的时间 (Presence interval, PI)。昆虫的出现前期会受到多种因素的影响, 其中最主要的影响因素是现场的温度条件, 因此通过建立适当的温度模型能够对其进行推断。如 Matuszewski 和 Mađra-Bielewicz (2016) 建立了一个指数回归模型来推断黄角尸葬甲、大隐翅虫 *Creophilus maxillosus* 和赤足郭公虫等的出现前期, 结果显示该方法推算得到的 PAI 比先前实验中得到的月平均 PAI 更为准确。但目前仅有部分昆虫物种含有此类模型, 并且对于一些重要的昆虫 (如丽蝇科) 使用温度数据难以推断 PAI (Archer, 2014; Matuszewski *et al.*, 2014)。在这种情况下, 法医昆虫学家需要对动物尸体 (最好是成年家猪的尸体) 上的昆虫群落演替进行大量研究, 以产生较好的参考数据。至于昆虫的存在时间 PI, 尤其是成虫的 PI, 比 PAI 有更复杂的成因背景, 对 PI

的预测面临着更多的不准确性。目前在推断昆虫的存在时间时仅能参考相关研究中得到的数据 (Matuszewski, 2021)。国内外学者已通过实验得到了一些昆虫的 PAI 和 PI 数据, 但这些数据还不够全面, 特别是室内现场需要得到更多的关注。

最后, 使用动物尸体 (一般是成年家猪) 开展的昆虫群落演替实验能够积累大量的相关数据, 有助于验证 PMI 推断方法的准确性 (Vanlaerhoven, 2008)。在对昆虫的演替进行初步验证研究时, 使用动物尸体开展实验特别适合 (Matuszewski *et al.*, 2020)。虽然最终的实验要回归到人类尸体上, 但目前对成年家猪尸体上昆虫演替规律的研究应成为法医昆虫学领域优先研究的内容之一。目前关于尸体上昆虫组成与演替的研究已在多个国家开展, 实验所涉及的环境条件包括室内、森林和沙漠等, Matuszewski 等 (2020) 对此进行了归纳。而我国已报道的相关研究仅有 20 余篇, 来自 13 个省的 17 个城市 (表 3)。考虑到不同地区的气候与生物群落等存在一定的差异, 有必要在我国的不同地区建立相应的昆虫群落演替模型。

表 3 我国关于尸体腐败和昆虫群落演替的研究进展
Table 3 Research progress on body decomposition and insect succession in China

地区 Regions	实验材料 Experimental materials	季节/月份 Season/Month	昆虫种类 Insect species	参考文献 References
北京 Beijing	人类尸体 Human corpse	3-8 月 March to August	鞘翅目: 38 种 Coleoptera: 38 species	周红章等, 1997
北京 Beijing	人类内脏 Human viscera	3-11 月 March to November	双翅目: 14 种 Diptera: 14 species	杨玉璞等, 1998
浙江杭州 Hangzhou, Zhejiang	猪肉 Pork meat	所有季节 All seasons	双翅目: 12 种; 鞘翅目: 16 种; 膜翅目: 2 种 Diptera: 12 species; Coleoptera: 16 species; Hymenoptera: 2 species	胡萃, 1997
黑龙江哈尔滨 Heilongjiang, Harbin	猪肉 Pork meat	春、夏、秋 Spring, summer, autumn	双翅目: 8 种; 鞘翅目: 19 种 Diptera: 8 species; Coleoptera: 19 species	李玲等, 2002
四川成都 Chengdu, Sichuan	兔子 Rabbit	5-11 月、3-9 月 May to November, March to September	双翅目: 5 种 Diptera: 5 species	王晔等, 2003
广东中山 Zhongshan, Guangdong	猪 Pig	秋、冬 Autumn and winter	38 种昆虫 Total: 38 species	陈强胜, 2006
内蒙古呼和浩特 Hohhot, Inner Mongolia	兔子、狗 Rabbit, dog	7-10 月 July to October	双翅目: 10 种 Diptera: 10 species	常云峰等, 2006

续表 3 (Table 3 continued)

地区 Regions	实验材料 Experimental materials	季节/月份 Season/Month	昆虫种类 Insect species	参考文献 References
广东珠三角 Pearl River Delta, Guangdong	猪 Pig	所有季节 All seasons	双翅目: 17 种; 鞘翅目: 16 种; 其他: 9 种 Diptera: 17 species; Coleoptera: 16 species; Other: 9 species	Wang <i>et al.</i> , 2008
广东广州 Guangzhou, Guangdong	兔子 Rabbit	春、夏 Spring and summer	双翅目: 10 种; 鞘翅目: 7 种 Diptera: 10 species; Coleoptera: 7 species	吴殿鹏等, 2008
河南三门峡 Sanmenxia, Henan	兔子 Rabbit	7-10 月 July to October	13 种昆虫 Total: 13 species	董迎春等, 2009
贵州贵阳 Guiyang, Guizhou	人类尸体 Human corpse	所有季节 All seasons	双翅目: 11 种 Diptera: 11 species	陈禄仕等, 2009
陕西西安 Xi'an, Shanxi	兔子 Rabbit	春 Spring	双翅目: 10 种; 鞘翅目: 4 种; 其他: 2 种 Diptera: 10 species; Coleoptera: 4 species; Other: 2 species	聂唐粉等, 2010
广东广州 Guangzhou, Guangdong	兔子 Rabbit	夏 Summer	49 种昆虫 Total: 49 species	Shi <i>et al.</i> , 2009
湖南永州 Yongzhou, Hunan	兔子 Rabbit	7-9 月 July to September	26 种昆虫 Total: 26 species	蒋莹等, 2011
广东深圳 Shenzhen, Guangdong	猪 Pig	夏 Summer	19 种昆虫 Total: 19 species	尹晓钧等, 2014
山东青岛 Qingdao, Shandong	猪 Pig	所有季节 All seasons	双翅目: 23 种 Diptera: 23 species	姜德志等, 2014
重庆 Chongqing	猪 Pig	所有季节 All seasons	94 种昆虫 Total: 94 species	吕宙, 2015
江苏苏州 Suzhou, Jiangsu	猪 Pig	夏、秋 Summer and autumn	双翅目: 16 种; 鞘翅目: 12 种; 其他: 5 种 Diptera: 16 species; Coleoptera: 12 species; Other: 5 species	杨利军, 2017
河南新乡 Xinxiang, Henan	兔子、鼠 Rabbit, rat	7-8 月 July to August	双翅目: 7 种 Diptera: 7 species	武红艳等, 2017
广东广州 Guangzhou, Guangdong	猪 Pig	夏 Summer	双翅目: 16 种; 鞘翅目: 8 种; 膜翅目: 6 种 Diptera: 16 species; Coleoptera: 8 species; Hymenoptera: 6 species	Wang <i>et al.</i> , 2017b
广东深圳 Shenzhen, Guangdong	人类尸体、猪、兔子 Human corpse, pig, rabbit	8-12 月 August to December	42 种昆虫 Total: 42 species	Wang <i>et al.</i> , 2017a

4 昆虫发育与演替的影响因素

4.1 温度条件

昆虫的发育及群落演替与死亡现场的温度条件密切相关 (Michaud and Moreau, 2009;

Matuszewski and Szafałowicz, 2013), 因此在使用昆虫证据推断死亡时间时需要重建温度条件, 且 PMI 推断的准确性在很大程度上取决于温度条件重建的准确性。研究人员一般使用距离死亡现场最近的气象站提供的温度数据, 同时也会根

据现场测量的实际温度进行调整(Archer, 2004; Hofer *et al.*, 2017, 2020; Johnson *et al.*, 2012; Lutz and Amend, 2020), 调整基于对这两组数据的线性回归分析(Charabidze and Hedouin, 2019)。虽然这种方法目前使用较少(Lutz and Amend, 2020), 但有可靠的实验数据表明, 调整后的温度更符合死亡现场的具体情况(Archer, 2004; Hofer *et al.*, 2020; Johnson *et al.*, 2012; Lutz and Amend, 2020)。研究人员已在多种类型的现场对温度条件进行了研究, Dadour 等(2011)针对停放在阳光下的车辆开发了一个简单的“温室”模型, Moreau 等(2021)研究了隐藏在行李箱、垃圾桶和密封桶中的尸体的温度数据, 建立了影响因素模型, Michalski 和 Nadolski(2018)收集了地窖、阁楼与拖车等封闭空间处的温度数据并将其与当地气象站的相应数据进行了比较。这些研究揭示了不同现场中尸体所处环境的真实温度条件, 具有重要的指导意义。

但需要注意, 尸体上昆虫的生活环境要更为复杂。一方面, 不同昆虫在尸体上的分布位置有所不同。昆虫可能分布在尸体的表面、内部、下方以及周围的泥土中等不同的位置, 这些位置的温度与现场的空气温度之间有一定的差异(马孟云等, 2016)。另一方面, 昆虫发育经历的实际温度还会受到昆虫群产热作用的影响: 尸体上因幼虫聚集而导致的产热现象较为常见, 这会大大缩短幼虫发育所需的时间。丽蝇幼虫聚集体中的产热现象已得到广泛研究(Turner and Howard, 1992; Slone and Gruner, 2007; Charabidze *et al.*, 2011; Rivers *et al.*, 2011; Heaton *et al.*, 2014; Johnson and Wallman, 2014; Kotzé *et al.*, 2016; Aubernon *et al.*, 2016, 2019; Gruner *et al.*, 2017; Podhorna *et al.*, 2018), 最近 Matuszewski 和 Mądra-Bielewicz(2021)报道了黄角尸葬甲(葬甲科)的产热情况, 并且发现热量源于甲虫遗留在尸体表面的分泌物。Johnson 等(2014)对丽蝇幼虫开展的实验发现它们非常倾向于聚集体中温度最高的部分。考虑到这种现象, 研究人员在推断死亡时间时很可能会使用相关实验中得

到的昆虫最短发育时间, 然而这些发育数据通常是在恒定的高温下得到的, 与昆虫的实际发育情况仍存在一定的差异。Heaton 等(2018)的研究数据显示, 幼虫在聚集体的外围和内部之间不断移动, 其待在外围的时间从 16%到 68%(平均 43%)不等。因此, 聚集体中的最高温度并非幼虫发育所经历的真实温度, 幼虫发育获得的热增益与其个体选择有关(Johnson *et al.*, 2014; Aubernon *et al.*, 2016; Gruszka *et al.*, 2020)。图 1 展示了 Gruszka 等(2020)在实验中发现的黄角尸葬甲不同龄期幼虫个体对发育所处温度的选择情况。为了更加准确地推断昆虫的虫龄, 进一步的研究需要使用跟踪技术来监测聚集体中不同幼虫获得的热增益和发育情况, 以获知幼虫的最短发育时间以及个体的真实发育情况。

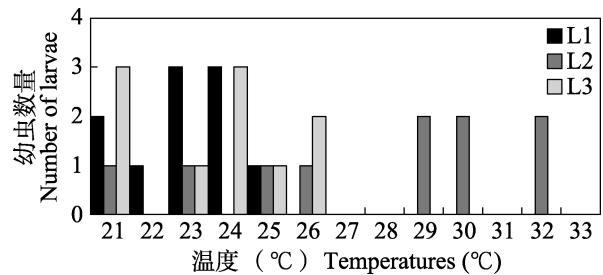


图 1 黄角尸葬甲幼虫在 20-40 °C 温度梯度上的分布 (Gruszka *et al.*, 2020)

Fig. 1 Distribution of individual *Necrodes littoralis* larvae in a thermal gradient of 20-40 °C (Gruszka *et al.*, 2020)

L1: 1 龄幼虫; L2: 2 龄幼虫; L3: 3 龄幼虫。

L1: 1st instar larvae; L2: 2nd instar larvae;

L3: 3rd instar larvae.

总而言之, 在推断尸体的死亡时间时需要得知昆虫发育所经历的实际温度条件, 而这会受到诸如现场环境、气候及昆虫个体选择等多种因素的共同影响。只有尽可能地将这些因素都考虑进去, 并且在进行现场勘查时在尸体周围的不同位置多收集温度数据, 才能保证昆虫虫龄推断的准确性。国内外学者为此展开了相关研究, 如 Charabidze 和 Hedouin(2019)通过对影响温度的多种因素进行优先排序和量化分析, 开发出了一种算法来校正温度数据。尽管这些研究很难开发出一些通用的方法来解决涉及到微气象学等

的复杂而敏感的问题,但这为以后更加深入的研究建立了一定的基础。

4.2 毒(药)物的影响

在我国,法医昆虫毒理学的研究主要集中于毒(药)物对昆虫生长发育的影响。大量研究表明,人或动物尸体组织中含有的某些毒(药)物会通过食物链转移到昆虫中,使其生长速度和发育历期受到影响,从而导致死亡时间的推断出现偏差(田洁, 2004; 戴军, 2005; 王丽娟, 2006; 赵文爱等, 2008; Liu *et al.*, 2009; Shi *et al.*, 2010; 吕宙等, 2012; Zou *et al.*, 2013; Wang *et al.*, 2020b; 王世雯, 2020)。

法医昆虫学家探究各种毒(药)物对昆虫生长和发育的影响,发现一些化学药品能够加速昆虫的发育。田洁(2004)及赵文爱等(2008)发现吗啡能够加速大头金蝇和丝光绿蝇的发育,导致幼虫体长和体重的增加,在进行 PMI 推断时偏差最高可达 84 h。戴军(2005)研究发现安定类药物会缩短丝光绿蝇幼虫的发育历期为 55 h。而包含马拉硫磷及酒精在内的一部分化学物会抑制昆虫的生长,如有研究发现马拉硫磷可抑制大头金蝇幼虫和蛹的生长,使其发育历期延长 36 h,最大体长缩短 1.1 mm (Liu *et al.*, 2009)。此外,对不同研究人员的实验结果进行结合分析可以发现,一些化学物质(如氯胺酮和甲基苯丙胺等)对不同物种昆虫的影响结果有所不同(Bhardwaj *et al.*, 2020)。如 Mahmood 和 Kareem (2019)使用牛肝开展的实验发现甲基苯丙胺会加快白头裸金蝇 *Chrysomya albiceps* 的发育,而王世雯(2020)则发现兔子尸体中的甲基苯丙胺会抑制巨尾阿丽蝇的生长发育。吕宙等(2012)的研究表明氯胺酮能抑制大头金蝇幼虫生长发育速度并相应延长发育历期,Zou 等(2013)则发现氯胺酮缩短了丝光绿蝇幼虫的发育历期。同种毒(药)物对不同蝇种生长发育产生的影响可能会存在显著的差异,其机制需要得到进一步的研究。总的来说,毒(药)物对昆虫生长发育产生的影响复杂多样,这使得法医昆虫学者难以将实验中得到的结论进行类比和推广,研究人员需要展开一系列的实验来全面系统地把握这

种影响。

作为法医昆虫学的一个分支,法医昆虫毒理学在 20 世纪末至 21 世纪初曾得到广泛的研究,然而这一领域的研究近年来逐渐减少。关于毒(药)物对昆虫生长发育产生的影响,国内外的研究人员已经通过大量实验实现了定性分析,但对这种影响进行的量化分析仍然较难实现,化学药品的剂量与昆虫发育速度、体长体重等的变化情况之间的对应关系仍不够准确(da Silva *et al.*, 2017)。要克服现有的瓶颈,还需采用新技术展开进一步的研究。此外,随着各种新型毒品和新精神活性物质等的出现和使用,全国各地发生的中毒死亡案件也更加多样,这迫切要求法医昆虫毒理学取得进一步的发展。

4.3 其他条件

除了上述影响因素,昆虫的发育与演替还与死亡现场的光照、湿度及海拔等条件有关(Mona *et al.*, 2019)。陈禄仕(2004)在贵州的不同地区 and 不同海拔高度用猪肺做诱饵设置了 12 个采样点,在一年的四个季度中,每个季度在每个采样点各收集一次昆虫证据,观察其中包含的昆虫种类,结果显示蝇类在猪肺上的分布在不同海拔高度和不同季节存在差异。此外, Kirstin 等(2017)发现昆虫在白天的产卵率高于夜间,王禹(2017)在实验中发现尸体的放置时刻会对尸体腐败进程和昆虫区系造成影响,但这并不影响人们利用尸体腐败和昆虫演替规律推断死亡时间(王禹等, 2021)。总之,昆虫的生长发育与群落演替等具有复杂的成因背景,在重建犯罪现场和推断死亡时间时,应尽可能多地将这些因素考虑进去。

5 法医昆虫学面临的挑战

作为法医学的分支学科,法医昆虫学在命案现场死亡时间的推断中已经得到了应用(王禹等, 2021),运用相关知识能够较为准确地推断死亡时间,但其进一步的发展仍面临诸多挑战。首先,法医昆虫学的理论还处于不断发展阶段,许多相关研究还有待开展,这具体体现在以下几

点。第一, 现有方法难以准确推断苍蝇和甲虫的蛹龄。对于腐烂尸体, 蝇类和甲虫的蛹是信息丰富的昆虫证据, 许多重要昆虫的蛹内发育规律已得到研究 (Ramos-Pastrana *et al.*, 2017; Flissak and Moura, 2018; Salazar-Souza *et al.*, 2018; Wang *et al.*, 2018a; da Silva and Moura, 2019), 但对蛹龄的推断还不够准确。第二, 法医昆虫毒理学的相关研究还不够完善。毒(药)物对昆虫生长发育的影响复杂多样(如同种化学物质对不同昆虫发育速度的影响可能截然相反), 现有方法难以对这种影响进行准确的量化分析, 因此毒(药)物对昆虫代谢规律的影响机制需要得到进一步的研究。第三, 对昆虫群落演替规律的研究还较为不足。为了更加准确地推断昆虫的出现前期和存在时间, 需要加强嗜尸性昆虫侵殖尸体的机理研究, 充分考虑现场环境条件和尸体自身因素的影响。第四, 进一步的发展需要加强学科融合(王禹等, 2021), 促进人工智能及基因组学等技术在法医昆虫学中的应用。通过对昆虫进行全线粒体基因组测序能够更加准确地鉴定昆虫的种属, 对卷积神经网络等智能算法的应用也有助于昆虫种属的鉴定和发育模型的构建。

法医昆虫学在实际应用方面也存在一系列的问题。第一, 尸体上昆虫发育与群落演替的相关数据还极为有限, 相关实验仅在我国的一小部分城市得到了开展。考虑到这种规律存在的区域差异性, 研究人员需要对不同地区的具体情况进行研究。第二, 国际统一的法医昆虫学现场操作规程尚未形成。在对昆虫证据进行处理时会涉及到昆虫的灭活与保存, 不同的操作方法对昆虫体长和体重的影响有所不同, 这会影响昆虫发育数据的质量 (Richards and Villet, 2008, 2009; Midgley and Villet, 2009; Frątczak-Łagiewska and Matuszewski, 2019), 并使得不同来源的数据难以进行比较和进一步分析。第三, 我国的公安机关中大部分的现场勘查人员缺乏法医昆虫学的基本知识, 同时视频侦查和大数据技术等办案技术的飞速发展也使得刑侦人员对法医昆虫学的需求有所降低, 这些都不利于法医昆虫学的发展与应用。

6 总结与展望

经过将近 30 年的发展, 我国的法医昆虫学在司法实践领域发挥着越来越重要的作用, 但其在死亡案件中的全面应用还远未实现。我国已报道的法医昆虫学应用案例仅有 20 余起 (彭家法和夏元飞, 1999; 王存友, 2003; 陈禄仕, 2007; 余礼聪等, 2008; 顾建明等, 2009; Guo *et al.*, 2011b; 廖明庆等, 2012; 王江峰等, 2012; 李学博等, 2013; Ying *et al.*, 2013; 魏智伟和黄安海, 2016; Wang *et al.*, 2018b, 2019a; Hu *et al.*, 2019, 2020a), 其中最主要的应用是通过昆虫证据推断死亡时间。在分析昆虫证据时, 蝇类的发育历期 (Developmental duration) 和幼虫体长是最常用的虫龄估算指标, 已在 10 起案例中得到了应用。也有一些案例运用蝇类形态特征的变化规律推断死亡时间, 而昆虫群落演替规律的应用目前仅有 1 例 (Wang *et al.*, 2019a)。

面对大数据技术等各种新兴办案技术的挑战, 法医昆虫学者必须加强本领域的基础研究, 通过应用全基因组测序、基因差异表达和人工智能等新技术, 实现更加准确的死亡时间推断 (夏冰等, 2014; 王启燕等, 2015)。为了实现法医昆虫学的大规模应用, 需要做到以下几点: 全面系统地收集昆虫证据, 在分析昆虫证据时将尸体自身状况和现场环境条件等因素考虑在内; 在进行昆虫的种属鉴定和发育时间推算时确保准确无误; 开展更加深入的研究以了解昆虫的群落演替机制及毒(药)物对昆虫的影响机制等; 注意不同生态地理环境中昆虫发育及演替规律的差异; 对刑事侦查人员开展法医昆虫学基础知识的培训。

参考文献 (References)

- Amendt J, Richards CS, Campobasso CP, Zehner R, Hall MJR, 2011. Forensic entomology: Applications and limitations. *Forensic Sci., Med. Pathol.*, 7(4): 379–392.
- Archer M, 2014. Comparative analysis of insect succession data from Victoria (Australia) using summary statistics versus preceding mean ambient temperature models. *J. Forensic Sci.*, 59(2): 404–412.

- Archer MS, 2004. The effect of time after body discovery on the accuracy of retrospective weather station ambient temperature corrections in forensic entomology. *J. Forensic Sci.*, 49(3): 553–559.
- Auberon C, Boulay J, Hedouin V, Charabidze D, 2016. Thermoregulation in gregarious dipteran larvae: Evidence of species-specific temperature selection. *Entomol. Exp. Appl.*, 160(2): 101–108.
- Auberon C, Hedouin V, Charabidze D, 2019. The maggot, the ethologist and the forensic entomologist: Sociality and thermoregulation in necrophagous larvae. *J. Adv. Res.*, doi: 10.1016/j.jare.2018.12.001.
- Bajerlein D, Taberski D, Matuszewski S, 2018. Estimation of postmortem interval (PMI) based on empty puparia of *Phormia regina* (Meigen) (Diptera: Calliphoridae) and third larval stage of *Necrodes littoralis* (L.) (Coleoptera: Silphidae)-Advantages of using different PMI indicators. *J. Forensic Leg. Med.*, doi: 10.1016/j.jflm.2018.02.008.
- Byrne AL, Camann MA, Cyr TL, Catts EP, Espelie KE, 1995. Forensic implications of biochemical differences among geographic populations of the black blow fly, *Phormia regina* (Meigen). *J. Forensic Sci.*, 40(3): 372–377.
- Bhardwaj T, Sharma S, Dalal J, Verma K, 2020. The implication of morphometrics and growth rate of dipteran flies in forensic entomotoxicology research: a review. *Sci. Nat.*, 107(6): 50–50.
- Cai JF, 2011. Modern and Practical Forensic Entomology. Beijing: People's Medical Publishing House. 1–4. [蔡继峰, 2011. 现代法医昆虫学. 北京: 人民卫生出版社. 1–4.]
- Carlson DA, Service MW, 1979. Differentiation between species of the *Anopheles gambiae* Giles complex (Diptera: Culicidae) by analysis of cuticular hydrocarbons. *Ann. Trop. Med. Parasitol.*, 73(6): 589–592.
- Carlson DA, Langley PA, Huyton P, 1978. Sex pheromone of the tsetse fly: Isolation, identification, and synthesis of contact aphrodisiacs. *Science*, 201(4357): 750–753.
- Chang YF, Cai JF, Deng ZH, Lan LM, Wang ZX, Liang WB, Deng RL, Li MY, Dong JG, Zhang JL, Zhou XR, Liao ZG, 2006. The constitution and succession of sarcosaphagous flies community in Hohhot. *Forensic Sci. Technol.*, 31(4): 14–17. [常云峰, 蔡继峰, 邓振华, 兰玲梅, 王震侠, 梁伟波, 邓仁丽, 李茂阳, 董建国, 张嘉陵, 周晓蓉, 廖志钢, 2006. 呼和浩特夏秋季嗜尸性苍蝇群落组成与演替. 刑事技术, 31(4): 14–17.]
- Charabidze D, Bourel B, Gosset D, 2011. Larval-mass effect: Characterisation of heat emission by necrophagous blowflies (Diptera: Calliphoridae) larval aggregates. *Forensic Sci. Int.*, 211(1/3): 61–66.
- Charabidze D, Hedouin V, 2019. Temperature: The weak point of forensic entomology. *J. Leg. Med.*, 133(2): 633–639.
- Chen LS, 2004. The species and distribution of the necrophagous flies in Guizhou Province. *Acta Entomol. Sin.*, 47(6): 849–853. [陈禄仕, 2004. 贵州省尸食性蝇类的种类和分布. 昆虫学报, 47(6): 849–853.]
- Chen LS, 2007. Estimating the postmortem interval using the accumulated degree days. *Chinese Journal of Forensic Medicine*, 22(4): 236–237. [陈禄仕, 2007. 利用积温和昆虫发育历期推测死亡时间的研究. 中国法医学杂志, 22(4): 236–237.]
- Chen LS, Qiu LC, Guo JC, Lin Y, 2009. Initial research on process of necrophagous flies participating in decomposing corpse parenchyma in four seasons. *Chinese Journal of Forensic Medicine*, 24(3): 188–190. [陈禄仕, 邱林川, 郭金昌, 林毅, 2009. 四季尸食性蝇类参与尸体软组织分解过程初探. 中国法医学杂志, 24(3): 188–190.]
- Chen LS, 2013. Necrophagous Flies in China. Guiyang: Guizhou Science and Technology Press. 3–34. [陈禄仕, 2013. 中国尸食性蝇类. 贵阳: 贵州科技出版社. 3–34.]
- Chen Q, Bai J, Liu L, Lin HB, Tang H, Zhao W, Zhou HZ, Yan JW, Liu YC, Hu SN, 2009. Sequential analysis of mitochondrial COI gene for seven common sarcosaphagous flies (Diptera) in Beijing and the establishment of their DNA barcodes. *Acta Entomol. Sin.*, 52(2): 202–209. [陈庆, 白洁, 刘力, 林红斌, 唐晖, 赵伟, 周红章, 严江伟, 刘雅诚, 胡松年, 2009. 北京地区 7 种常见嗜尸性蝇类的 COI 基因序列分析及 DNA 条形码的建立. 昆虫学报, 52(2): 202–209.]
- Chen QS, 2006. Study on the characteristics of cadaver decomposition and the disciplinary of arthropod successional patterns in cadaver at suburban districts of Zhongshan. Master dissertation. Guangzhou: Sun Yat-sen University. [陈强胜, 2006. 中山市尸食性昆虫在尸体降解过程中演替规律的研究. 硕士学位论文. 广东: 中山大学.]
- Chen W, Shang YJ, Ren LP, Xie K, Zhang XY, Zhang CQ, Sun SL, Wang Y, Zha LY, Guo YD, 2018. Developing a MtSNP-based genotyping system for genetic identification of forensically important flesh flies (Diptera: Sarcophagidae). *Forensic Sci. Int.*, doi: 10.1016/j.forsciint.2018.07.012.
- Chen W, Yang L, Ren LP, Shang YJ, Wang SW, Guo YD, 2019. Impact of constant versus fluctuating temperatures on the development and life history parameters of *Aldrichina grahami* (Diptera: Calliphoridae). *Insects*, 10(7): 184.

- da Silva EIT, Wilhelmi B, Villet MH, 2017. Forensic entomotoxicology revisited-towards professional standardisation of study designs. *J. Leg. Med.*, 131(5): 1399–1412.
- da Silva SM, Moura MO, 2019. Intrapuparial development of *Hemilucilia semidiaphana* (Diptera: Calliphoridae) and its use in forensic entomology. *J. Med. Entomol.*, 56(6): 1623–1635.
- Dadour IR, Almanjahie I, Fowkes ND, Keady G, Vijayan K, 2011. Temperature variations in a parked vehicle. *Forensic Sci. Int.*, 207(1/3): 205–211.
- Dai J, 2005. Effect of diazepam on the growth and development of *Lucilia sericata* (Diptera Calliphoridae) and its forensic importance. Master dissertation. Shijiazhuang: Hebei Medical University. [戴军, 2005. 安定对丝光绿蝇幼虫生长发育的影响及其法医学意义. 硕士学位论文. 石家庄: 河北医科大学.]
- Dong YC, Zhu Y, Wang L, Dong CZ, Liao ZG, 2009. Primary study on common species sarcosaphagous flies. *Forensic Sci. Technol.*, 34(2): 14–16. [董迎春, 朱怡, 王磊, 董春泽, 廖志钢, 2009. 河南三门峡地区夏秋季常见嗜尸性蝇类的初步研究. 刑事技术, 34(2): 14–16.]
- Fan ZD, 1957a. Calliphora in China. *Acta Entomol. Sin.*, 7(3): 321–348. [范滋德, 1957a. 中国的丽蝇属. 昆虫学报, 7(3): 321–348.]
- Fan ZD, 1957b. The identification keys of commonfly larvae in Shanghai. *Acta Entomol. Sin.*, 7(4): 405–422. [范滋德, 1957b. 上海常见蝇类幼虫小志. 昆虫学报, 7(4): 405–422.]
- Feng DX, Liu GC, 2013. Pupal age estimation of forensically important *Megaselia spiracularis* Schmitz (Diptera: Phoridae). *Forensic Sci. Int.*, 231 (1/3): 199–203.
- Feng DX, Liu GC, 2014. Pupal age estimation of forensically important *Megaselia scalaris* (Loew)(Diptera: Phoridae). *Forensic Sci. Int.*, doi: 10.1016/j.forsciint.2014.01.002.
- Feng DX, Wu J, Sun DP, 2021. Intrapuparial age estimation of forensically important *Dohrniphora cornuta* (Diptera: Phoridae). *J. Med. Entomol.*, 58(2): 616–624.
- Flissak JC, Moura MO, 2018. Intrapuparial development of *Sarconesia chlorogaster* (Diptera: Calliphoridae) for postmortem interval estimation (PMI). *J. Med. Entomol.*, 55(2): 277–284.
- Frątczak-Łagiewska K, Matuszewski S, 2019. The quality of developmental reference data in forensic entomology: Detrimental effects of multiple, in vivo measurements in *Creophilus maxillosus* L. (Coleoptera: Staphylinidae). *Forensic Sci. Int.*, doi: 10.1016/j.forsciint.2019.02.059.
- Gan YX, 1958. Chrysomya in China. *Acta Entomol. Sin.*, 8(4): 340–350. [甘运兴, 1958. 中国的金蝇. 昆虫学报, 8(4): 340–350.]
- Goff ML, 2000. A Fly for the Prosecution: How Insect Evidence Helps Solve Crimes. Cambridge: Harvard University Press. 14–17.
- Gruner SV, Slone DH, Capinera JL, Turco MP, 2017. Volume of larvae is the most important single predictor of mass temperatures in the forensically important calliphorid, *Chrysomya megacephala* (Diptera: Calliphoridae). *J. Med. Entomol.*, 54(1): 30–34.
- Gruszka J, Krystkowiak-Kowalska M, Frątczak-Łagiewska K, Mądra-Bielewicz A, Charabidze D, Matuszewski S, 2020. Patterns and mechanisms for larval aggregation in carrion beetle *Necrodes littoralis* (Coleoptera: Silphidae). *Anim. Behav.*, doi: 10.1016/j.anbehav.2020.01.011.
- Gu JM, Zhang JZ, Sun Z, Zhang WJ, Qin BL, Cao SY, 2009. Estimation of the discarding time of a dismembered corpse. *Forensic Sci. Technol.*, 34(4): 75–76. [顾建明, 张继宗, 孙政, 张文杰, 秦蓓蕾, 曹森炎, 周凌, 2009. 杀人分尸案的抛尸时间推断. 刑事技术, 34(4): 75–76.]
- Guo F, 1952. Sarcophagidae in Shanghai. *Acta Entomol. Sin.*, 2(1): 60–86. [郭郭, 1952. 上海麻蝇小志. 昆虫学报, 2(1): 60–86.]
- Guo YD, Cai JF, Li X, Xiong F, Su RN, Chen FL, Liu QL, Wang XH, Chang YF, Zhong M, Wang X, Wen JF, 2010. Identification of the forensically important sarcophagid flies *Boertcherisca peregrina*, *Parasarcophaga albiceps* and *Parasarcophaga dux* (Diptera: Sarcophagidae) based on COII gene in China. *Trop. Biomed.*, 27(3): 451–460.
- Guo YD, Cai JF, Chang YF, Li X, Liu QL, Wang XH, Wang X, Zhong M, Wen JF, Wang JF, 2011a. Identification of forensically important sarcophagid flies (Diptera: Sarcophagidae) in China, based on COI and 16S rDNA gene sequences. *J. Forensic Sci.*, 56(6): 1534–1540.
- Guo YD, Cai JF, Tang ZC, Feng X, Lin Z, Yong F, Li JB, Chen YQ, Meng FM, Wen JF, 2011b. Application of *Aldrichina grahami* (Diptera, Calliphoridae) for forensic investigation in central-south China. *Rom. J. Leg. Med.*, 19(1): 55–58.
- Guo YD, Cai JF, Meng FM, Chang YF, Gu Y, Lan LM, Liang L, Wen JF, 2012. Identification of forensically important flesh flies based on a shorter fragment of the cytochrome oxidase subunit I gene in China. *Med. Vet. Entomol.*, 26(3): 307–313.
- Guo YD, Zha LY, Yan WT, Li P, Cai JF, Wu LX, 2014. Identification of forensically important sarcophagid flies (Diptera: Sarcophagidae) in China based on COI and period gene. *Int. J. Legal. Med.*, 128(1): 221–228.
- Harvey ML, Gaudieri S, Villet MH, Dadour IR, 2008. A global study

- of forensically significant calliphorids: Implications for identification. *Forensic Sci. Int.*, 177(1): 66–76.
- Heaton V, Moffatt C, Simmons T, 2014. Quantifying the temperature of maggot masses and its relationship to decomposition. *J. Forensic Sci.*, 59(3): 676–682.
- Heaton V, Moffatt C, Simmons T, 2018. The movement of fly (Diptera) larvae within a feeding aggregation. *Can. Entomol.*, 150(3): 326–333.
- Hofer IMJ, Hart AJ, Martín-Vega D, Hall MJR, 2017. Optimising crime scene temperature collection for forensic entomology casework. *Forensic Sci. Int.*, doi: 10.1016/j.forsciint.2016.11.019.
- Hofer IMJ, Hart AJ, Martín-Vega D, Hall MJR, 2020. Estimating crime scene temperatures from nearby meteorological station data. *Forensic Sci. Int.*, 306, doi: 10.1016/j.forsciint.2019.110028.
- Hu C, 1997. A preliminary study on the species and biological characters of necrophagous insects in Hangzhou area. *J. Zhejiang Agric. Univ.*, 23(4):19–24. [胡萃, 1997. 杭州地区尸食性昆虫种类与生物学特性的初步研究. 浙江农业大学学报, 23(4): 19–24.]
- Hu C, 2000. Forensic Entomology. Chongqing: Chongqing Publishing Group. 1–2. [胡萃, 2000. 法医昆虫学. 重庆: 重庆出版社. 1–2.]
- Hu GL, Wang M, Wang Y, Liao MQ, Hu JY, Zhang YN, Yu YM, Wang JF, 2020a. Estimation of post-mortem interval based on insect species present on a corpse found in a suitcase. *Forensic Sci. Int.*, doi: 10.1016/j.forsciint.2019.110046.
- Hu GL, Wang M, Wang Y, Tang HH, Chen RF, Zhang YN, Zhao YL, Jin JY, Wang YF, Wu MW, Wang JF, 2020b. Development of *Necrobia rufipes* (De Geer, 1775)(Coleoptera: Cleridae) under constant temperatures and its implication in forensic entomology. *Forensic Sci. Int.*, doi: 10.1016/j.forsciint.2020.110275.
- Hu GL, Wang Y, Sun Y, Zhang YN, Wang M, Wang JF, 2019. Development of *Chrysomya rufifacies* (Diptera: Calliphoridae) at constant temperatures within its colony range in Yangtze River Delta region of China. *J. Med. Entomol.*, 56(5): 1215–1224.
- Jackson LL, Baker GL, 1970. Cuticular lipids of insects. *Lipids*, 5(2): 239–246.
- Jens A, Carlo PC, Emmanuel G, Christian R, Hélène NL, Martin H, 2007. Best practice in forensic entomology-standards and guidelines. *J. Leg. Med.*, 121(2): 90–104.
- Jiang DZ, Zhan XL, Sun KW, Gu Y, Ren W, Li BZ, Zhang P, Li WH, 2014. Study on the common species and seasonal succession of necrophagous flies in Qingdao region. *Chinese Journal of Forensic Medicine*, 29(5): 460–464. [姜德志, 战雪蕾, 孙坤伟, 顾耘, 任卫, 李宝增, 张平, 李卫华, 2014. 青岛地区常见嗜尸性蝇种及其季节性分布研究. 中国法医学杂志, 29(5): 460–464.]
- Jiang Y, Cai JF, Yang L, Yi WP, Lan LM, Li X, Li JB, 2011. A study of sarcosaphagous insects from Arthropod in Yongzhou district of Hunan province. *Chinese Journal of Applied Entomology*, 48(1): 191–196. [蒋莹, 蔡继峰, 杨玲, 易文平, 兰玲梅, 李响, 李剑波, 2011. 湖南省永州地区夏秋季常见嗜尸性昆虫的研究. 应用昆虫学报, 48(1): 191–196.]
- Johnson AP, Wallman JF, 2014. Effect of massing on larval growth rate. *Forensic Sci. Int.*, doi: 10.1016/j.forsciint.2014.05.006.
- Johnson AP, Wallman JF, Archer MS, 2012. Experimental and casework validation of ambient temperature corrections in forensic entomology. *J. Forensic Sci.*, 57(1): 215–221.
- Johnson AP, Wighton SJ, Wallman JF, 2014. Tracking movement and temperature selection of larvae of two forensically important blow fly species within a “maggot mass”. *J. Forensic Sci.*, 59(6): 1586–1591.
- Kirstin AW, James FW, Bryan DL, Christopher RJK, Mazungula DN, Martin HV, 2017. Nocturnal oviposition behavior of blowflies (Diptera: Calliphoridae) in the southern hemisphere (South Africa and Australia) and its forensic implications. *Forensic Sci., Med., Pathol.*, 13(2): 123–134.
- Kotzé Z, Villet MH, Weldon CW, 2016. Heat accumulation and development rate of massed maggots of the sheep blowfly, *Lucilia cuprina* (Diptera: Calliphoridae). *J. Insect Physiol.*, doi: 10.1016/j.jinsphys.2016.09.009.
- Li L, Zhang YF, Ma YK, 2002. The major necrophagous insects and their regular activity on carcass in Harbin. *Northeast Forest Univ.*, 32(5): 93–96. [李玲, 张幼芳, 马玉堃, 2002. 哈尔滨地区常见尸食性昆虫及在猪尸上出现的规律. 东北林业大学学报, 32(5): 93–96.]
- Li LL, Wang Y, Wang JF, 2016a. Intra-puparial development and age estimation of forensically important *Hermetia illucens* (L.). *J. Asia-Pac. Entomol.*, 19(1): 233–237.
- Li LL, Wang Y, Wang JF, Ma MY, Lai Y, 2016b. Temperature-dependent development and the significance for estimating postmortem interval of *Chrysomya nigripes* Aubertin, a new forensically important species in China. *J. Leg. Med.*, 130(5): 1363–1370.
- Li QC, Shi QX, Lei YY, Lin T, Qi GJ, He YR, Lv LH, 2019. Advances on research and techniques for insect cuticular hydrocarbons analysis and their practice in chemical taxonomy in China. *J. Environ. Entomol.*, 41(1): 62–69. [李群臣, 石庆型,

- 雷妍圆, 林涛, 齐国君, 何余容, 吕利华, 2019. 中国昆虫表皮碳氢化合物与昆虫化学分类学的研究进展. *环境昆虫学报*, 41(1): 62–69.]
- Li XB, Gong Q, Wan LH, Jiang D, Jiao YG, 2013. A case of estimating the time of death by necrophagous flies. *Chinese Journal of Forensic Medicine*, 28(3): 248–249. [李学博, 巩强, 万立华, 江东, 焦亚光, 2013. 利用嗜尸性蝇类辅助推断死亡时间 1 例. *中国法医学杂志*, 28(3): 248–249.]
- Li YY, 2007. Effect of temperature on the growth and development of the larvae of *Lucilia sericata* (Diptera: Calliphoridae) and its significance in forensic medicine. Master dissertation. Shijiazhuang: Hebei Medical University. [李艳宇, 2007. 温度对丝光绿蝇幼虫生长发育的影响及其法医学意义. 硕士学位论文. 石家庄: 河北医科大学.]
- Liao MQ, Li ZG, Wang JF, Luo SM, Ma T, 2012. Insects can also be found on bodies that are severely burned in winter. *Journal of Political Science and Law*, 29(1): 112–115. [廖明庆, 李志刚, 王江峰, 罗思敏, 马婷, 2012. 冬季且被严重焚烧的尸体上也会有昆虫. *政法学刊*, 29(1): 112–115.]
- Liu QL, Cai JF, Chang YF, Yan G, Guo YD, Wang XH, Weng JF, Zhong M, Wang X, Yang L, Wu KL, Lan LM, Wang JF, Chen YQ, 2011. Identification of forensically important blow fly species (Diptera: Calliphoridae) in China by mitochondrial cytochrome oxidase I gene differentiation. *Insect Sci.*, 18(5): 554–564.
- Liu X, Shi Y, Wang H, Zhang R, 2009. Determination of malathion levels and its effect on the development of *Chrysomya megacephala* (Fabricius) in South China. *Forensic Sci. Int.*, 192(1/3): 14–18.
- Liu ZY, Han H, Chen W, Wang SW, Meng FM, Cai JF, Guo YD, 2021. Evaluation of reference genes and age estimation of forensically useful *Aldrichina grahami* (Diptera: Calliphoridae) during intrapuparial period. *J. Med. Entomol.*, 58(1): 47–55.
- Luo SD, Halstead DGH, 1989. Stored product beetle retrieval. *Cereals Oils*, 2(2): 63. [罗淑德, Halstead DGH, 1989. 贮藏产品甲虫检索. *粮食与油脂*, 2(2): 63.]
- Lutz L, Amendt J, 2020. Stay cool or get hot? An applied primer for using temperature in forensic entomological case work. *Sci. Justice*, 60(5): 415–422.
- Lü Z, 2015. Insect succession on carcasses in southern Chongqing city and its forensic application. Doctoral dissertation. Chongqing: Chongqing Medical University. [吕宙, 2015. 重庆市南部地区嗜尸性昆虫群落演替及其法医学应用. 博士学位论文. 重庆: 重庆医科大学.]
- Lü Z, Tang R, Yang YQ, Hao JW, Wan LH, 2015. Progress on sarcosaphagous insect fauna succession and its forensic implications. *Chinese Journal of Forensic Medicine*, 30(2): 166–170. [吕宙, 唐瑞, 杨永强, 郝建文, 万立华, 2015. 嗜尸性昆虫群落演替及其法医学应用研究进展. *中国法医学杂志*, 30(2): 166–170.]
- Lü Z, Wan LH, 2016. Insect Evidence and its application in postmortem interval estimation. *Foren. Sci. Technol.*, 41(5): 352–356. [吕宙, 万立华, 2016. 昆虫证据在死亡时间推断中的应用. *刑事技术*, 41(5): 352–356.]
- Lü Z, Zhai XD, Zhou HM, Li P, Ma JQ, Guan L, Mo YN, 2012. Effect of ketamine on the development of *Chrysomya megacephala* (Diptera: Calliphoridae). *Chin. J. Parasitol. Parasitic Dis.*, 30(5): 361–366. [吕宙, 翟仙敦, 周海梅, 李朴, 马锦琦, 官玲, 莫耀南, 2012. 氯胺酮对大头金蝇生长发育的影响. *中国寄生虫学与寄生虫病杂志*, 30(5): 361–366.]
- Ma MY, Wang Y, Dong YY, Wang JF, 2016. Discussion on forensic entomology standards and guidelines for the on-site operation. *Forensic Sci. Technol.*, 41(2): 142–146. [马孟云, 王禹, 董玉友, 王江峰, 2016. 法医昆虫学检验现场操作标准探讨. *刑事技术*, 41(2): 142–146.]
- Ma T, Huang J, Wang JF, 2015. Study on the pupal morphogenesis of *Chrysomya rufifacies* (Macquart)(Diptera: Calliphoridae) for postmortem interval estimation. *Forensic Sci. Int.*, doi: 10.1016/j.forsciint.2015.06.005.
- Ma YK, Hu C, Min JX, 1998. Effects of temperature on the growth and development of four common necrophagous flies and their significance in forensic medicine. *Chinese Journal of Forensic Medicine*, 13(2): 81–84. [马玉堃, 胡萃, 闵建雄, 1998. 温度对 4 种常见尸食性蝇类生长发育的影响及其法医学意义. *中国法医学杂志*, 13(2): 81–84.]
- Mahmood HR, Kareem MA, 2019. Impact of Methamphetamine on the life cycle stages of two forensically important flies in AL-Diwanayah city. *Journal of Punjab Academy of Forensic Medicine & Toxicology*, 19(2): 53–56.
- Matuszewski S, 2021. Post-mortem interval estimation based on insect evidence: Current challenges. *Insects*, 12(4): 314.
- Matuszewski S, Anna MB, 2019. Post-mortem interval estimation based on insect evidence in a quasi-indoor habitat. *J. Forensic Sci. Soc.*, 59(1): 109–115.
- Matuszewski S, Hall MJR, Moreau G, Schoenly KG, Tarone AM, Villet MH, 2020. Pigs vs people: The use of pigs as analogues for humans in forensic entomology and taphonomy research. *J. Leg. Med.*, 134(2): 793–810.

- Matuszewski S, Mądra-Bielewicz A, 2016. Validation of temperature methods for the estimation of pre-appearance interval in carrion insects. *Forensic Sci., Med., Pathol.*, 12(1): 50–57.
- Matuszewski S, Mądra-Bielewicz A, 2021. Heat production in a feeding matrix formed on carrion by communally breeding beetles. *Front. Zool.*, 18(1): 1–11.
- Matuszewski S, Szafałowicz M, 2013. Temperature-dependent appearance of forensically useful beetles on carcasses. *Forensic Sci. Int.*, 229(1/3): 92–99.
- Matuszewski S, Szafałowicz M, Grzywacz A, 2014. Temperature-dependent appearance of forensically useful flies on carcasses. *J. Leg. Med.*, 128(6): 1013–1020.
- Meng FM, Ren LP, Wang ZY, Deng JQ, Guo YD, Chen C, Dmitrijs F, Cai JF, 2017. Identification of forensically important blow flies (Diptera: Calliphoridae) in China based on COI. *J. Med. Entomol.*, 54(5): 1193–1200.
- Michalski M, Nadolski J, 2018. Thermal conditions in selected urban and semi-natural habitats, important for the forensic entomology. *Forensic Sci. Int.*, doi: 10.1016/j.forsciint.2018.03.042.
- Michaud JP, Moreau G, 2009. Predicting the visitation of carcasses by carrion-related insects under different rates of degree-day accumulation. *Forensic Sci. Int.*, 185(1/3): 78–83.
- Midgley JM, Villet MH, 2009. Effect of the killing method on post-mortem change in length of larvae of *Thanatophilus micans* (Fabricius 1794)(Coleoptera: Silphidae) stored in 70% ethanol. *J. Leg. Med.*, 123(2): 103–108.
- Mona S, Khalid M, Jawad M, Noreen S, Rakha A, 2019. Forensic entomology: A comprehensive review. *Adv. Life Sci.*, 6(2): 48–59.
- Moore HE, Adam CD, Drijfhout FP, 2014. Identifying 1st instar larvae for three forensically important blowfly species using “fingerprint” cuticular hydrocarbon analysis. *Forensic Sci. Int.*, doi: 10.1016/j.forsciint.2014.04.002.
- Moreau G, Lutz L, Amendt J, 2021. Honey, can you take out the garbage can? Modeling weather data for cadavers found within containers. *Pure Appl. Geophys.*, 178(3): 745–756.
- Nie TF, Wei CM, Tian YF, Tian F, Lian ZM, 2010. Primary study on sarcosaphagous insects on rabbit carcass in Xi'an. *Chinese Bulletin of Entomology*, 47(3): 587–591. [聂唐粉, 魏朝明, 田英芳, 田飞, 廉振民, 2010. 西安地区家兔尸体上尸食性昆虫的初步观察. *昆虫知识*, 47(3): 587–591.]
- Owings CG, Spiegelman C, Tarone AM, Tomberlin JK, 2014. Developmental variation among *Cochliomyia macellaria* Fabricius (Diptera: Calliphoridae) populations from three ecoregions of Texas, USA. *J. Leg. Med.*, 128(4): 709–717.
- Peng JF, Xia YF, 1999. The application of forensic entomology in three cases. *Journal of Forensic Medicine*, 15(2): 60. [彭家法, 夏元飞, 1999. 法医昆虫学在 3 例检案中的应用. *法医学杂志*, 15(2): 60.]
- Peng QY, Ye LS, Ma LP, Cai JF, 2009. The succession of sarcophagus beetles on carrion and its application in forensic medicine. *Journal of Forensic Medicine*, 25(6): 447–450. [彭倩宜, 叶鲁思, 马丽平, 蔡继峰, 2009. 嗜尸性甲虫在尸体上的演替及其法医学应用前景. *法医学杂志*, 25(6): 447–450.]
- Podhorna J, Aubernon C, Borkovcova M, Boulay J, Hedouin V, Charabidze D, 2018. To eat or get heat: Behavioral trade-offs between thermoregulation and feeding in gregarious necrophagous larvae. *Insect Sci.*, 25(5): 883–893.
- Ramos-Pastrana Y, Londoño CA, Wolff M, 2017. Intra-puparial development of *Lucilia eximia* (Diptera, Calliphoridae). *Acta Amazonica*, 47(1): 63–70.
- Ran Y, Zhang XY, Lv Z, 2021. Research progress on species identification of sarcosaphagous flies. *Journal of Forensic Medicine*, 37(3): 305–317. [冉渊, 张小园, 吕宙, 2021. 嗜尸性蝇类种属鉴定研究进展. *法医学杂志*, 37(3): 305–317.]
- Ren LP, Chen W, Shang YJ, Meng FM, Zha LY, Wang Y, Guo YD, 2018. The application of COI gene for species identification of forensically important muscid flies (Diptera: Muscidae). *J. Med. Entomol.*, 55(5): 1150–1159.
- Ren LP, Shang YJ, Guo YD, 2021. Progress and Application of Entomological Evidence in Forensic Science. *Journal of Forensic Medicine*, 37(3): 295–304. [任立品, 尚艳杰, 郭亚东, 2021. 昆虫学证据在法庭科学中的应用及进展. *法医学杂志*, 37(3): 295–304.]
- Richards CS, Paterson ID, Villet MH, 2008. Estimating the age of immature *Chrysomya albiceps* (Diptera: Calliphoridae), correcting for temperature and geographical latitude. *J. Leg. Med.*, 122(4): 271–279.
- Richards CS, Villet MH, 2008. Factors affecting accuracy and precision of thermal summation models of insect development used to estimate post-mortem intervals. *J. Leg. Med.*, 122(5): 401–408.
- Richards CS, Villet MH, 2009. Data quality in thermal summation development models for forensically important blowflies. *Med. Vet. Entomol.*, 23(3): 269–276.
- Rivers DB, Thompson C, Brogan R, 2011. Physiological trade-offs of forming maggot masses by necrophagous flies on vertebrate

- carrion. *Bull. Entomol. Res.*, 101(5): 599–611.
- Salazar-Souza M, Couri MS, Aguiar VM, 2018. Chronology of the intrapuparial development of the blowfly *Chrysomya albiceps* (Diptera: Calliphoridae): Application in forensic entomology. *J. Med. Entomol.*, 55(4): 825–832.
- Shang YJ, Ren LP, Chen W, Zha LY, Cai JF, Dong JN, Guo YD, 2019. Comparative mitogenomic analysis of forensically important sarcophagid flies (Diptera: Sarcophagidae) and implications of species identification. *J. Med. Entomol.*, 56(2): 392–407.
- Shang YJ, Ren LP, Yang L, Wang SW, Chen W, Dong JN, Ma HM, Qi X, Guo YD, 2020. Differential gene expression for age estimation of forensically important *Sarcophaga peregrina* (Diptera: Sarcophagidae) intrapuparial. *J. Med. Entomol.*, 57(1), 65–77.
- Shi YW, Liu XS, Wang HY, Zhang RJ, 2009. Seasonality of insect succession on exposed rabbit carrion in Guangzhou, China. *Insect Sci.*, 16(5): 425–439.
- Shi YW, Liu XS, Wang HY, Zhang RJ, 2010. Effects of malathion on the insect succession and the development of *Chrysomya megacephala* (Diptera: Calliphoridae) in the field and implications for estimating postmortem interval. *J. Forensic Med. Pathol.*, 31(1): 46–51.
- Slone DH, Gruner SV, 2007. Thermoregulation in larval aggregations of carrion-feeding blow flies (Diptera: Calliphoridae). *J. Med. Entomol.*, 44(3): 516–523.
- Sperling FAH, Anderson GS, Hickey DA, 1994. A DNA-based approach to the identification of insect species used for postmortem interval estimation. *J. Forensic Med.*, 39(2): 418–427.
- Su RN, Guo YD, Xie D, Peng YL, Cai JF, Hua F, Sheng LH, 2013. Identification of forensically important beetles (Coleoptera: Histeridae) in China based on 16S rRNA and Cyt b. *Trop. Biomed.*, 30(3): 375–387.
- Tartivita K, Jackson LL, 1970. Cuticular lipids of insects. I. hydrocarbons of *Leucophaea maderae* and *Blatta orientalis*. *Lipids*, 5(1): 35–47.
- Tian J, 2004. Effect of morphine in tissues on development of *Chrysomya megacephala* (Diptera: Calliphoridae) and implication of this effect on estimation of postmortem intervals using arthropod development patterns. Master dissertation. Shijiazhuang: Hebei Medical University. [田洁, 2004. 吗啡对大头金蝇生长发育的影响及其在死后间隔时间推断方面的应用. 硕士学位论文. 石家庄: 河北医科大学.]
- Turner B, Howard T, 1992. Metabolic heat generation in dipteran larval aggregations: A consideration for forensic entomology. *Med. Vet. Entomol.*, 6(2): 179–181.
- Vanlaerhoven SL, 2008. Blind validation of postmortem interval estimates using developmental rates of blow flies. *Forensic Sci. Int.*, 180(2/3): 76–80.
- Wang CY, 2003. Application of forensic entomology in solving a case. *Forensic Sci. Technol.*, 38(5): 60–61. [王存友, 2003. 利用法医昆虫学破案 1 例. 刑事技术, 38(5): 60–61.]
- Wang H, Wang L, Li ZM, 2008. Pupal morphogenesis of *Lucilia cuprina* in different constant temperatures and its significance in forensic medicine. *Chinese Journal of Forensic Medicine*, 23(5): 324–326, 361. [王贺, 王玲, 李泽民, 2008. 不同温度下铜绿蝇蛹期发育形态观察. 中国法医学杂志, 23(5): 324–326, 361.]
- Wang HY, Shi YW, Liu XS, Zhang RJ, 2010. Growth and development of *Boettcherisca peregrine* under different temperature conditions and its significance in forensic entomology. *J. Environ. Entomol.*, 32(2): 166–172. [汪海洋, 时燕薇, 刘小山, 张润杰, 2010. 不同温度条件下棕尾别麻蝇的生长发育及其在法医学上的意义. 环境昆虫学报, 32(2): 166–172.]
- Wang JF, 1999. Fundamental research on the application of morphology and development patterns of some necrophagous flies in the determination of postmortem interval. Doctoral dissertation. Zhejiang: Zhejiang University. [王江峰, 1999. 若干尸食性蝇类形态学及生长发育规律用于死后间隔时间判断的基础研究. 博士学位论文. 浙江: 浙江大学.]
- Wang JF, Chang P, Liao MQ, Li ZG, Ma T, Gui LF, Yu LC, 2012. On the application of forensic entomology to the investigation of indoor, outdoor and poisoning death cases in Guangdong province. *J. Political Sci. Law*, 29(1): 116–121. [王江峰, 常鹏, 廖明庆, 李志刚, 马婷, 桂凌峰, 余礼聪, 2012. 广东省室内、室外及中毒死亡案件中法医昆虫学的应用报道. 政法学刊, 29(1): 116–121.]
- Wang JF, Li ZG, Chen YC, Chen QS, Yin XH, 2008. The succession and development of insects on pig carcasses and their significances in estimating PMI in south China. *Forensic Sci. Int.*, 179(1): 11–18.
- Wang JF, Li ZG, Yu LC, Chen QS, Huang AH, Liao MQ, Xie YT, Chen YC, 2008. Succession and development of insects on pig carcasses and their significances in estimating PMI in the Pearl River Delta region. *Acta Entomol. Sin.*, 51(4): 402–410. [王江峰, 李志刚, 余礼聪, 陈强盛, 黄安海, 廖明庆, 谢云铁, 陈玉川, 2008. 珠江三角洲猪尸体上昆虫群落的演替及其对法医学中死亡时间推断的指示意义. 昆虫学报, 51(4): 402–410.]
- Wang L, Liu B, Li ZM, 2008. Chronometrical morphology changes

- of larval cephalopharyngeal skeleton in the different developmental stages of *Parasarcophaga crassipalpis* and its application in forensic medicine. *Chinese Bulletin of Entomology*, 45(1): 133–137, 176. [王玲, 刘彬, 李泽民, 2008. 肥须亚麻蝇幼虫头咽骨形态学分析及其法医学意义. 昆虫知识, 45(1): 133–137, 176.]
- Wang LJ, 2006. Effect of Diazepam in tissues on development of *Chrysomya megacephala* (Diptera) and implication of this effect on estimation of postmortem intervals using arthropod development patterns. Master dissertation. Shijiazhuang: Hebei Medical University. [王丽娟, 2006. 不同温度下安定对大头金蝇生长发育的影响及其在死后间隔时间推断方面的应用. 硕士学位论文. 石家庄: 河北医科大学.]
- Wang M, Chu J, Wang Y, Li FG, Liao MQ, Shi H, Zhang YN, Hu GL, Wang JF, 2019a. Forensic entomology application in China: Four case reports. *J. Forensic Leg. Med.*, doi: 10.1016/j.jflm.2019.03.001.
- Wang M, Wang Y, Hu GL, Wang YH, Xu W, Wu MW, Wang JF, 2020a. Development of *Lucilia sericata* (Diptera: Calliphoridae) under constant temperatures and its significance for the estimation of time of death. *J. Med. Entomol.*, 57(5): 1373–1381.
- Wang QY, Zhou H, Liang Q, Huang J, Dai JL, Wang J, Zhang HL, 2015. Morphological characteristics and gene expression of *Aldrichina graham* egg in different developmental stages. *Chin. J. Publ. Heal.*, 31(5): 617–619. [王启燕, 周昊, 梁芹, 黄江, 戴佳琳, 王杰, 张红玲, 2015. 巨尾阿丽蝇卵不同发育时间形态变化及基因表达. 中国公共卫生, 31(5): 617–619.]
- Wang SW, 2020. A forensic study of the effect of methamphetamine on the development of *Aldrichina grahami* (Diptera: Calliphoridae). Master dissertation. Urumqi: Xinjiang Medical University. [王世雯, 2020. 甲基苯丙胺对巨尾阿丽蝇生长发育影响的法医学研究. 硕士学位论文. 乌鲁木齐: 新疆医科大学.]
- Wang SW, Zhang CQ, Chen W, Ren LP, Ling J, Shang YJ, Guo YD, 2020b. Effects of methamphetamine on the development and its determination in *Aldrichina grahami* (Diptera: Calliphoridae). *J. Med. Entomol.*, 57(3): 691–696.
- Wang Y, 2017. Study on the changes of sarcosaprophagous insects and carcasses in the Yangtze River Delta region. Doctoral dissertation. Guangzhou: South China Agricultural University. [王禹, 2017. 长三角地区嗜尸性昆虫及尸体变化研究. 博士学位论文. 广州: 华南农业大学.]
- Wang Y, Gu ZY, Xia SX, Wang JF, Zhang YN, Tao LY, 2018a. Estimating the age of *Lucilia illustris* during the intrapuparial period using two approaches: morphological changes and differential gene expression. *Forensic Sci. Int.*, doi: 10.1016/j.forsciint.2018.02.025.
- Wang Y, Hu GL, Zhang YN, Wang M, Amendt J, Wang JF, 2019b. Development of *Muscina stabulans* at constant temperatures with implications for minimum postmortem interval estimation. *Forensic Sci. Int.*, doi: 10.1016/j.forsciint.2019.02.051.
- Wang Y, Li LL, Wang JF, Wang M, Yang LJ, Tao LY, Zhang YN, Hou YD, Chu J, Hou ZL, 2016. Development of the green bottle fly *Lucilia illustris* at constant temperatures. *Forensic Sci. Int.*, doi: 10.1016/j.forsciint.2016.07.019.
- Wang Y, Liao MQ, Wang YH, Gong Q, Xu W, Wang M, Zhang YN, Wang JF, 2021. Application of sarcosaprophagous insects to estimate the postmortem interval in 11 cases. *Journal of Forensic Medicine*, 37(3): 332–337. [王禹, 廖明庆, 王颖慧, 巩强, 徐旺, 王嫚, 张亚楠, 王江峰, 2021. 应用嗜尸性昆虫推断死亡时间 11 例. 法医学杂志, 37(3): 332–337.]
- Wang Y, Liu M, Sun DH, Ding Y, 2003. A study on sarcosaprophagous insects species variety with seasons in Chengdu. *Journal of Forensic Medicine*, 19(2): 86–87, 91. [王晔, 刘敏, 孙大宏, 丁勇, 2003. 成都市嗜尸昆虫种类季节变化研究. 法医学杂志, 19(2): 86–87, 91.]
- Wang Y, Ma MY, Jiang XY, Wang JF, Li LL, Yin XJ, Wang M, Lai Y, Tao LY, 2017a. Insect succession on remains of human and animals in Shenzhen, China. *Forensic Sci. Int.*, doi: 10.1016/j.forsciint.2016.12.032.
- Wang Y, Wang JF, Wang ZF, Tao LY, 2017b. Insect succession on pig carcasses using different exposure time-A preliminary study in Guangzhou, China. *J. Forensic Leg. Med.*, doi: 10.1016/j.jflm.2017.08.002.
- Wang Y, Wang JF, Zhang YN, Tao LY, Wang M, 2017c. Forensically important *Boettcherisca peregrina* (Diptera: Sarcophagidae) in China: development pattern and significance for estimating postmortem interval. *J. Med. Entomol.*, 54(6): 1491–1497.
- Wang Y, Wang M, Hu GL, Xu W, Wang YH, Wang JF, 2020c. Temperature-dependent development of *Omosita colon* at constant temperature and its implication for PMImin estimation. *J. Forensic Leg. Med.*, doi: 10.1016/j.jflm.2020.101946.
- Wang Y, Yang JB, Wang JF, Li LL, Wang M, Yang LJ, Tao LY, Chu J, Hou YD, 2017d. Development of the forensically important beetle *Creophilus maxillosus* (Coleoptera: Staphylinidae) at constant temperatures. *J. Med. Entomol.*, 54(2): 281–289.
- Wang Y, Yang LJ, Zhang YN, Tao LY, Wang JF, 2018b. Development of *Musca domestica* at constant temperatures and the first case report of its application for estimating the minimum

- postmortem interval. *Forensic Sci. Int.*, doi: 10.1016/j.forsciint. 2018.02.004.
- Wang Y, Zhang YN, Hu GL, Wang M, Zhu R, Zhai YS, Sun J, Li XF, Wang LH, Wu MW, Wang JF, 2020d. Development of *Megaselia spiracularis* (Diptera: Phoridae) at different constant temperatures. *J. Therm. Biol.*, doi: 10.1016/j.jtherbio.2020.102722.
- Wang Y, Zhang YN, Liu C, Hu GL, Wang M, Yang LJ, Chu J, Wang JF, 2018c. Development of *Aldrichina grahmi* (Diptera: Calliphoridae) at constant temperatures. *J. Med. Entomol.*, 55(6): 1402–1409.
- Wang Y, Zhang YN, Wang M, Hu GL, Fu YF, Zhi R, Wang JF, 2021. Development of *Hydrotaea spinigera* (Diptera: Muscidae) at constant temperatures and its significance for estimating postmortem interval. *J. Med. Entomol.*, 58(1): 56–63.
- Wei ZW, Huang AH, 2016. Estimating the postmortem interval of a composed body by regression equation of maggot. *Chinese Journal of Forensic Medicine*, 31(3): 316–317. [魏智伟, 黄安海, 2016. 蛆长推断死亡时间回归方程用于腐败尸体鉴定 1 例. 中国法医学杂志, 31(3): 316–317.]
- Wu DP, Mao RQ, Guo M, Zhou J, Jia FL, Ou GS, Zhang RJ, 2008. Species and succession of necrophagous insect community in spring and summer seasons in Guangzhou. *Acta Sci. Nat. Univ. Sunyatseni*, 47(6): 56–60. [吴殿鹏, 毛润乾, 郭明, 周健, 贾凤龙, 欧桂生, 张润杰, 2008. 广州市春夏季尸食性昆虫群落种类组成与演替. 中山大学学报(自然科学版), 47(6): 56–60.]
- Wu HY, Yang LQ, Wang B, Yuan HY, Zhai YJ, 2017. Study on the community succession of sarcosaphagous insects at summer in Xinxiang area. *Chinese Journal of Forensic Medicine*, 32(1): 13–15. [武红艳, 杨柳青, 王波, 袁皓月, 翟英杰, 2017. 新乡地区夏季常见嗜尸性昆虫群落演替规律初步研究. 中国法医学杂志, 32(1): 13–15.]
- Xia B, Liu YM, Wang QY, Zhang HL, Wang J, Dai JL, Huang J, 2014. Morphological characteristics and gene expression of *Chrysomya megacephala* eggs in different developmental stages. *Chin. J. Parasitol. Parasitic Dis.*, 32(4): 295–298. [夏冰, 刘玉铭, 王启燕, 张红玲, 王杰, 戴佳琳, 黄江, 2014. 大头金蝇卵不同发育时间形态变化及基因表达差异研究. 中国寄生虫学与寄生虫病杂志, 32(4): 295–298.]
- Xue WQ, 1976. One new species and three new records of the genus *Hydrotaea* from China (Diptera: Muscidae). *Acta Entomol. Sin.*, 19(1): 109–111. [薛万琦, 1976. 齿股蝇属一新种及三新纪录 (双翅目: 蝇科). 昆虫学报 19(1): 109–111.]
- Xue WQ, Verves YG, Du J, 2011. A review of subtribe *Boettcheriscina* Verves 1990 (Diptera: Sarcophagidae), with descriptions of a new species and genus from China. *Ann. Soc. Ent. Fr.*, 47(3/4): 303–329.
- Yang LJ, 2017. Succession and development of insects and their significances in estimating PMI in Yangtze River Delta region. Doctoral dissertation. Soochow: Soochow University. [杨利军, 2017. 长三角地区昆虫在尸体上的演替及发育规律用于死亡时间推断的研究. 博士学位论文. 苏州: 苏州大学.]
- Yang LJ, Wang Y, Li LL, Wang JF, Wang M, Zhang YN, Chu J, Liu K, Hou YD, Tao LY, 2017. Temperature-dependent development of *Parasarcophaga similis* (Meade 1876) and its significance in estimating postmortem interval. *J. Forensic Sci.*, 62(5): 1234–1243.
- Yang YP, Ren JC, Liu L, Li YW, Yan R, Wang XJ, Zhang XZ, 1998. Study on necrophagous mucoid flies living on human corpses in Beijing and its application on forensic medicine practice. *Chinese Journal of Forensic Medicine*, 13(3): 159–162. [杨玉璞, 任嘉诚, 刘力, 李彦文, 阎荣, 汪兴鉴, 张学忠, 1998. 北京地区尸生性蝇类研究及其在法医鉴定中的应用. 中国法医学杂志, 13(3): 159–162.]
- Yang YQ, Li XB, Shao RY, Lyu Z, Li HW, Li GP, Xu LZ, Wan LH, 2016. Developmental times of *Chrysomya megacephala* (Fabricius)(Diptera: Calliphoridae) at constant temperatures and applications in forensic entomology. *J. Forensic Sci.*, 61(5): 1278–1284.
- Yang YQ, Lyu Z, Li XB, Li K, Yao L, Wan LH, 2015. Development of *Hemipyrellia ligurriens* (Wiedemann)(Diptera: Calliphoridae) at constant temperatures: Applications in estimating postmortem interval. *Forensic Sci. Int.*, doi: 10.1016/j.forsciint. 2015.05.006.
- Ye GY, Li K, Zhu JY, Zhu GH, Hu C, 2007. Cuticular hydrocarbon composition in pupal exuviae for taxonomic differentiation of six necrophagous flies. *J. Med. Entomol.*, 44(3): 450–456.
- Ye LS, Peng QY, Cai JF, 2010. Research progress of factors affecting carcasses decomposition by sarcosaphagous insects. *J. Environ. Entomol.*, 32(4): 538–543. [叶鲁思, 彭倩宜, 蔡继峰, 2010. 嗜尸性昆虫分解尸体影响因素的研究进展. 环境昆虫学报, 32(4): 538–543.]
- Yin XJ, Ma MY, Zhou H, Lai Y, Wang JF, 2014. The community succession of sarcosaphagous insects on pig carcasses in summer indoor and outdoor environment in Shenzhen area. *J. Forensic Med.*, 30(3): 172–177. [尹晓钧, 马孟云, 周晖, 赖跃, 王江峰, 2014. 深圳地区夏季室内外猪尸体上嗜尸性昆虫的群落演替. 法医学杂志, 30(3): 172–177.]
- Ying L, Chen YQ, Guo YD, Zha LY, Li LJ, 2013. Estimation of post-mortem interval for a drowning case by using flies (Diptera) in central-south China: Implications for forensic entomology.

- Rom. J. Leg. Med., 21(4): 293–298.
- Yu LC, Lv GL, Wang JF, 2008. Using entomology to estimate the time of death: A case report. *Journal of Tropical Medicine*, 8(5): 519–520. [余礼聪, 吕国丽, 王江峰, 2008. 利用昆虫学推断死亡时间 1 例分析. 热带医学杂志, 8(5): 519–520.]
- Zhai XD, Zhao LL, Zheng Z, Zhang Z, Lü Z, Xia ZY, Mo YN, 2017. Molecular identification of five common Sarcophagidae species of necrophagous flies from Luoyang. *Chinese Journal of Forensic Medicine*, 32(5): 443–447, 452. [翟仙敦, 赵琳琳, 郑哲, 张振, 吕宙, 夏志远, 莫耀南, 2017. 洛阳地区 5 种嗜尸性麻蝇分子鉴定研究. 中国法医学杂志, 32(5): 443–447, 452.]
- Zhang MY, 1982. A study of the larvae of some common sarcophagid flies from China. *Entomotaxonomia*, 4(Z1): 93–106. [张孟余, 1982. 我国常见麻蝇幼虫的研究. 昆虫分类学报, 4(Z1): 93–106.]
- Zhang SF, Liu YP, 1985. A study on six species of Dermestidae. *Acta Zhengzhou Grain Coll.*, 6(3): 76–80. [张生芳, 刘永平, 1985. 对六种皮蠹科仓虫的探讨. 郑州粮食学院学报, 6(3): 76–80.]
- Zhang XY, Li Y, Shang YJ, Ren LP, Chen W, Wang SW, Guo YD, 2020. Development of *Sarcophaga dux* (Diptera: Sarcophagidae) at constant temperatures and differential gene expression for age estimation of the pupae. *J. Therm. Biol.*, doi: 10.1016/j.jtherbio.2020.102735.
- Zhang Y, Wang Y, Yang LJ, Tao LY, Wang JF, 2018. Development of *Chrysomya megacephala* at constant temperatures within its colony range in Yangtze River Delta region of China. *Forensic Sci. Res.*, 3(1): 74–82.
- Zhang YN, Wang Y, Liu C, Wang JF, Hu GL, Wang M, Yang LJ, Chu J, 2019a. Development of *Nasonia vitripennis* (Hymenoptera: Pteromalidae) at constant temperatures in China. *J. Med. Entomol.*, 56(2): 368–377.
- Zhang YN, Wang Y, Sun J, Hu GL, Wang M, Amendt J, Wang JF, 2019b. Temperature-dependent development of the blow fly *Chrysomya pinguis* and its significance in estimating postmortem interval. *R. Soc. Open Sci.*, 6(9): 190003.
- Zhang ZY, Ren LP, Leng J, Shang YJ, Zhu GH, 2019c. The complete mitochondrial genome of *Chrysomya nigripes* (Diptera: Calliphoridae). *Mitochondrial DNA*, 4(2): 4012–4013.
- Zhao B, Wang H, Wang L, Wang WJ, Li ZM, 2010. Chronometric morphological change of larvae of two species of necrophagous flies and its implication in forensic medicine. *Chinese Bulletin of Entomology*, 47(2): 360–367. [赵博, 王贺, 王玲, 王卫杰, 李泽民, 2010. 二种尸食性蝇类幼虫形态学变化及在法医学上的意义. 昆虫知识, 47(2): 360–367.]
- Zhao B, Wang L, Wang H, Wang WJ, Qi LL, Li ZM, 2009. Morphological changes of *Lucilia sericata* larvae and its significance in forensic medicine. *Chin. J. Vector. Biol. Control*, 20(6): 534–537. [赵博, 王玲, 王贺, 王卫杰, 齐莉莉, 李泽民, 2009. 丝光绿蝇幼虫不同温度下的形态学变化及法医学意义. 中国媒介生物学及控制杂志, 20(6): 534–537.]
- Zhao WA, Wang BX, Hu SA, Feng XY, 2008. The relationship between the postmortem interval and effects of morphine on the growth stage of *Lucilia sericata*. *J. Pathog. Biol.*, 3(8): 612–615, 618. [赵文爱, 王伯霞, 胡圣爱, 冯晓勇, 2008. 恒温条件下吗啡对丝光绿蝇发育规律改变与死者死亡时间推断的相关研究. 中国病原生物学杂志, 3(8): 612–615, 618.]
- Zhou HZ, Yang YP, Ren JC, Liu L, Wang SY, Yan R, Li YW, 1997. Studies of forensic entomology in Beijing district I. Sarcosaphagous beetles and their local specificity. *Acta Entomol. Sin.*, 40(1): 62–70. [周红章, 杨玉璞, 任嘉诚, 刘力, 王书永, 阎荣, 李彦文, 1997. 北京地区法医昆虫学研究 I. 嗜尸性甲虫物种多样性及其地区分异. 昆虫学报, 40(1): 62–70.]
- Zhuo L, Mao JX, Chen JS, Song P, Lin S, Xia SH, Chen H, 2020. COI and 16S rDNA sequence identification of common necrophagous flies in Fujian province. *Journal of Forensic Medicine*, 36(6): 749–754. [卓萃, 毛佳雄, 陈建山, 宋鹏, 林澍, 夏胜海, 陈煌, 2020. 福建省常见尸食性蝇类的 CO I 及 16S rDNA 序列鉴定. 法医学杂志, 36(6): 749–754.]
- Zou Y, Huang M, Huang RT, Wu XW, You ZJ, Lin JQ, Huang XY, Qiu XT, Zhang S, 2013. Effect of ketamine on the development of *Lucilia sericata* (Meigen) (Diptera: Calliphoridae) and preliminary pathological observation of larvae. *Forensic Sci. Int.*, 226(1): 273–281.