METHODOLOGICAL ASPECTS OF RESEARCH INTEGRITY AND CULTURE

Paper mill challenges: past, present, and future

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Abstract

Paper mills are fraudulent organizations that make money by writing fake manuscripts and offering authorship slots for sale to academic customers. Mill activity differs in scale to individual academic misconduct: many thousands of fake paper mill manuscripts have been successfully published in peer-reviewed journals. Despite this, paper mill activity is still relatively unrecognized outside the publishing industry. We discuss what is known about paper mill operations and how publishers, independent organizations, and individuals are working to prevent and detect mill activity. Research readers can also have a part to play in paper mill detection, and we provide detail on what to look out for. © 2024 The Author(s). Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

Keywords: Fraud; Meta-research; Paper mills; Publication ethics; Research ethics; Scientific misconduct

1. Introduction

In 2023, the Hindawi journals retracted over 8000 papers found to be the fraudulent output of paper mills [1]—commercial entities that write and sell scores of sham academic manuscripts to people wanting a journal publication. The Hindawi affair was large-scale fraud, far beyond the output of a single dishonest researcher and it sent shock waves through the publishing industry. Publishers, data sleuths, and researchers have been increasingly aware of paper mill activity for over a decade. Clear Skies, a company with a commercial paper mill detection tool, estimates that paper mill activity now accounts for >1.5% of the research literature [2]. The increased availability of artificial intelligence tools may mean fraudulent paper mill outputs are easier to produce and harder to detect. Despite this, many researchers, universities, and editors have still not heard of paper mills and don't know the signs. It's timely therefore to present a short history and modus operandi of paper mills, with the aim of increasing awareness and upskilling the general reader.

Paper mills appear to be a distinct entity from the more well-known problem of individual researcher misconduct (see Table 1) [3]. Mills are akin to organized crime [3], systematically producing and selling papers in bulk as a for-profit enterprise. Some of the behaviors may be similar: for example, a deceitful academic individual may falsify data [4], propose fake peer reviewers (with made-up email addresses that go to the author) [5], or sell authorship slots on their paper to fund the article processing charge or supplement their income [6] [personal communication, Nick Wise, 2024]. There is, however, a huge difference in scale, with paper mills potentially producing and submitting hundreds or thousands more fake papers per year than a lone miscreant. There is also typically a difference in focus: individualized research misconduct may be found at all stages of research, including high-profile clinical trials, and thus can affect meta-analyses and clinical guidelines with direct risk to the health of the public [3,7]. In contrast,

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What is new?

Key findings
- Paper mills are fraudulent organizations that make money by writing fake manuscripts and offering authorship slots for sale to academic customers.

- Paper mill outputs are large scale, and many thousands of fake manuscripts have been successfully published in peer-reviewed journals.

- Paper mill activity is still relatively unknown outside of the publishing industry, meaning that many researchers and readers do not know the signs.

What this adds to what is known?
- Paper mill activity can be suspected by the general reader if they are aware and informed about possible signs

What is the implication and what should change now?
- Research institutions should discuss paper mills during research integrity education sessions

- There is an urgent need for more research into tools that can detect paper mills before, during, and after the publication process

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paper mill papers typically focus on early-stage, seemingly low-stakes research, often wet laboratory studies, not always intended for a wide readership and unlikely to immediately threaten health or wellbeing. Nevertheless, fabricated research threatens loss of trust in academic research, and such studies can pollute the evidence base in a given topic. This could result in translational research that attempts to build on made-up studies, wasting research money, derailing scientific progression, and hampering career progression [8]. As large language models continue to rapidly evolve, paper mills could potentially leverage this capacity to supply high-profile manuscripts, including clinical trials, if there is sufficient commercial demand.

Much of what we know about paper mill operations and outputs comes from reports outside academic publishing: in-house notes on publishing company webpages, the news section of academic journals such as Science [9,10] and Nature News [2,11]; blogs including Retraction Watch [1] and Leonard Schneider's For Better Science [12]; comments on PubPeer (pubpeer.com). Some reports are posted under pseudonyms like Smut Clyde and Tiger. As paper mills have become more well known, a growing collection of academic literature is being published [8,13], including

editorials in journals that have been targeted by paper mills [14,15]. There are urgent calls for more research [8,13].

2. A short history of (what we think we know about) paper mills

Author suggestions for peer reviewers save editor time and deliver reports of similar quality (albeit more likely to be positive [16]) compared to reports from editor-sourced reviewers. However, in the early 2010s, academic publishers started suspecting organized manipulation of the peer review process [5,17]. Editors reported clusters of suspicious peer review different in scale and style to the occasional questionable peer review likely suspected of being faked by the author. This time the suspicious peer reviews appear in papers with diverse authors but were similar enough in style to indicate a common origin. These included very speedy, short, and universally positive reviews with bogus reviewer names reflecting old Hollywood stars or email addresses with names of legitimate academics but incorrect institutional strings [18]. When confronted, authors claimed that the paper submission/peer reviewer suggestion process had been outsourced to an external agency [19].

Editors rejected or retracted papers affected by fraudulent peer review including from so-called "peer review mills." Some journals removed the "suggest peer reviewer" function from their site, others added vetting policies to confirm peer reviewer identity and email addresses. Peer review mill activity is ongoing [20].

Around the same time, an article was published in Science reporting on companies based in China that offered scientific academic manuscripts for sale [10]. The companies offered various services, including writing up papers from clients' data and selling authorship slots on research papers written by other academics or by company staff (using, eg, data purchased from a third party or publicly available data to write meta-analyses). The Chinese market for ghostwritten papers in 2011 was independently valued at over US$4.4 million [21]. Other reports of companies offering similar services began to emerge from countries such as Iran [22] and Russia [23].

By the mid-late 2010s, there were signs that paper mills had moved to the next level: producing potentially fake papers using made-up data. In 2017, Byrne and colleagues [24] reported a cluster of five publications on an obscure cancer gene. The papers had no authorship overlap but showed unexpected similarities (beyond the uncommon topic) in text, order of figure types, font of figure legends, and using shared incorrect gene knockdown controls. Further examination revealed a total of 48 highly similar papers in this cluster that often featured the same incorrect control reagents. Image integrity experts including Bik [25] and Christopher [26] independently noticed spikes in image manipulation within scientific publications. They published

Table 1. Characteristics of paper mills vs dishonest researcher or research group [3]

	Paper mills	Researcher misconduct including problematic clinical trials
Origin	Commercial entity	Single researcher/small researcher group; may be clinician researcher
Author/fraudster relationship	Author is generally a paying customer; fraudsters may not appear on author list	Author is the fraudster
Scale	Large: hundred or more	Moderate: several/dozens
Publication focus	Low profile	Possibly high profile
Process	May be submitted by paper mill; if so, authorship can change during process	Submitted by author/fraudster
Submission	Multiple manuscripts with submission similarities	One manuscript at a time
Text/data sources	Text, tables, and/or images are copied from other sources	Text is unique, data may be unique (e.g., fabricated or falsified) or may be copied from unrelated papers

on patterns of photoshopped images in seemingly unrelated papers: cropped sections from images were flipped and duplicated in photographs of Western blots, histopathology, and immunofluorescence; repeating elements were seen in otherwise unconnected flow cytometry plots and bar graphs. The publishing and academic readership gradually understood that external companies, so-called "paper mills," were writing and selling fictitious scientific papers using made-up data and illustrated with duplicate or photoshopped images [27−29].

Many publishers already had strategies in place aimed at preventing or detecting problems in individual papers, informed by publishing industry bodies such as the Committee on Publication Ethics (COPE; publicationethics.org), International Committee of Medical Journal Editors (icmje.org), and the International Association of Scientific, Technical, and Medical Publishers (STM; stm-assoc.org). Some companies employed in-house expert statisticians to check methods and results and image integrity experts to scan for errors or evidence of misconduct [30]. They had already instituted requirements for conflict of interest disclosures and authorship-contribution statements and requested or required presubmission of clinical trial protocols [31]. The paper mill problem, however, was different and on a bigger scale. Research Integrity teams, which were beginning to be established at some publishers to deal with individual publication ethics cases, started to develop processes for prepublication identification and postpublication management of paper mill products. They upskilled in-house image screeners to look for signs of repeated, systematic fraud [26,30,32]. Third-party organizations like Clarivate [33] and researchers like Byrne and Labbé [34] started developing tools to automate the identification and discovery process. As a sign of how important this topic was viewed, Nature named Byrne as one of their "10 people who matter" in 2017 for her work uncovering paper mills [35].

Retractions from paper mill activity are increasing. The Retraction Watch database now attributes 6146 retractions to paper mills [36], an increase from the 1182 retractions attributed by mid-2022 [37]. There is a lack of empirical research about paper mills and it is not clear how much of the increase in retractions is due to increased paper mill activity, increased detection, or increased willingness of journals to issue retractions. Paper mill locations are not always known, but the use of paper mills has now been reported in authors located in many different countries. [9,12,38−40] Within the last year, new paper mill tactics have emerged: evidence of paper mills targeting journal editors [9,12,38,39]. Mills are offering large cash bribes to editors for publication of their products. They are also approaching journals with offers to guest-edit special issues, either with paper mill-friendly researchers, or their own staff posing as legitimate researchers using stolen identities [38].

3. The main players—consumers

The first reports of paper mills came from China and Chinese biomedical researchers, particularly medical professionals, were identified as the main consumers [37]. The requirements for Chinese scientists and clinicians to publish in order to progress through graduation and promotion [10], coupled with inadequate resources to carry out their own research and, in some universities at least, the promise of cash rewards, made them easy targets [41,42]. Paper mills offer a quick publication and their range of products include highly valued English language publications indexed in reputable bibliographic databases like PubMed and Journal Citation Reports [10,43]. Subsequent accounts have identified paper mills in other countries including India, Russia, and Iran [22,37,44]. Springer Nature identified senior Russian academics as the main consumers of one recently discovered mill (Svetlana Kleiner, personal communication, 2024).

The would-be consumer hears about paper mill products through word of mouth or via advertisements placed in
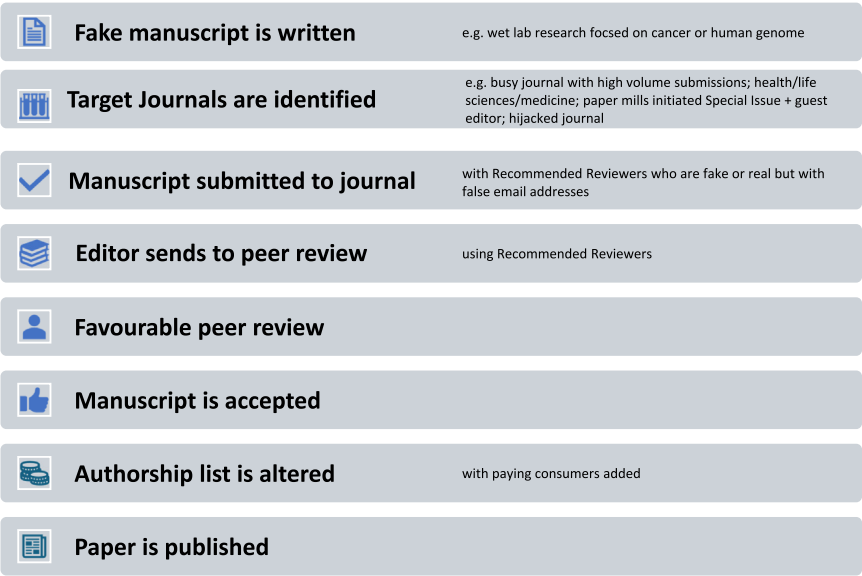
📄	Fake manuscript is written	e.g. wet lab research focsed on cancer or human genome
🏛	Target Journals are identified	e.g. busy journal with high volume submissions; health/life sciences/medicine; paper mills initiated Special Issue + guest editor; hijacked journal
✓	Manuscript submitted to journal	with Recommended Reviewers who are fake or real but with false email addresses
📚	Editor sends to peer review	using Recommended Reviewers
👤	Favourable peer review	
👍	Manuscript is accepted	
💰	Authorship list is altered	with paying consumers added
📰	Paper is published	

Figure. The process of paper mill operations.

WhatsApp groups, Facebook, or Telegram. The advertisement may mention services such as ghostwriting or authorship for sale [10]. Consumers may or may not know that the manuscripts are bogus.

4. The main players—paper mills

There are no first-hand accounts by paper mill operators about how these organizations work. The information presented here is gleaned from people posing as would-be consumers and from research into paper mill processes and outputs by publishers and readers; for example, [3,8−10,12,24,44] (See Fig.).

Paper mill staff seem likely to write a series of similar bogus papers, perhaps wet lab research focused on cancer, a suitable topic for a medical professional. The bulk of the text is reused across multiple papers, including Titles, Acknowledgments statements. The Results are illustrated with repurposed or falsified images and graphs, often Western blots, microscopy photos, bar graphs, and scatter plots. These can be easily copied from other sources and modified with photoshop tools.

A target journal is identified, perhaps a busy Medicine, Life Sciences, or Health journal with a high volume of submissions. Journals are often broad in scope: since editors in chief cannot be an expert in all areas covered by the journal, submitted manuscripts are assigned directly to a handling editor. This means no one person is seeing everything, and patterns are harder to spot. Manuscripts may be submitted to multiple journals simultaneously, with fake emails for suggested peer reviewers. A paper mill may offer bribes to the journal editor or suggest a special issue with themselves as the guest editor, using a fake email address to pose as a reputable academic. Some paper mills may have established links with a "hijacked journal" (a form of journal "identity theft" using a sham online copy of a legitimate journal that steals author fees in return for publication in what the author assumes is the real journal) [45].

The journal editor, either bogus, in the pay of the paper mill, or legitimate but busy with editorial duties on top of their main job [46], sends the manuscript out for peer review using one or more of the suggested reviewers. Peer reviews are favorable and the paper is accepted, subject to minor revisions. The paper mill advertises the provisionally accepted product through their usual channels (WhatsApp, Telegram, Facebook) and negotiates a price with consumers. Prices are likely to be higher for first author position and for papers in high impact-factor journals.

The mill completes the minor revisions and adds the paid customers as new authors. If necessary, this is justified to the journal by citing the expertise required to complete the revisions, but many journals previously allowed authorship changes without justification. After a series of sequential authorship changes, many of the "authors" are paid customers. The bogus paper is published and adds to the existing body of (legitimate) evidence on that subject.

5. The main players—detectives

Somebody notices something is wrong in a single paper or as a pattern across several papers [47,48]. Perhaps a journal editor, even a busy one, notices a spike in submissions on similar obscure topics from the same country or notices what appears to be the same manuscript with different titles being submitted multiple times. Perhaps the in-house image screener at the publishing company notices a repeating

Table 2. Screening for paper mill activity [3,30,37,39,50–52]

Suspicious back-end/publisher-only information

- ○ Suspicious cover letters

  - Letter is absent
  - Letter details do not match manuscript (eg different title)
  - Letter is identical to cover letters for unrelated manuscripts

- ○ Suspicious author matters

  - Requests to add new authors after acceptance
  - Submitting author has multiple user accounts in the same journal
  - Multiple submissions from author at same time
  - Multiple submissions of same manuscript from same IP address but with different authors
  - Response to requests for raw data are absent OR similar in tone or content to responses from other suspected/known paper mill papers, eg repeated phrases from seemingly different authors; supplying high volume of poorly labeled data files

- ○ Suspicious peer reviewer matters

  - Peer review is very rapid, superficial
  - Peer reviewer email address does not conform to institutional format
  - IP address of submitting author is the same as peer reviewer
  - Guest editors consistently achieve very rapid transition times through submission—peer review—acceptance

Suspicious elements of submitted manuscript or linked publications

- ○ Text anomalies

  - Variable writing style/phrasing throughout one manuscript
  - Textual similarities to unrelated papers (eg title format, identical font in headings and Figure/Table legends)
  - Use of unusual/"tortured" phrases suggesting manuscript has been run through plagiarism software [53]

- ○ Image anomalies

  - Manipulated/photoshopped images (cropped, flipped, repeated)
  - Commonly seen in Western blots, histopathology photos, flow cytometry plots
  - Suspected use of stock images: clean background, unlabeled Western blots, too-perfect scatter plots
  - Images/texts/graphs similar in order or format to those of unrelated papers

- ○ Method inaccuracies

  - Use of bogus cell lines, wrongly identified experimental reagents

- ○ Problematic citations

  - Unrelated to topic

(Continued)

Table 2. Continued

- ○ Suspicious bibliographic information

  - Listed doi does not link to any paper
  - Journal has a bogus website
  - Publication is not indexed in any bibliographic databases

- ○ Associated data shows irregularities

  - Email addresses of authors do not conform to institutional format
  - Ethics/grant numbers are faked

- ○ Critical comments on Retraction Watch/Pub Peer

pattern of manipulated images across different submissions [26]. Perhaps an academic with an interest in a specific, rare topic, and an alert set up to notify them of new publications on that subject, realizes that after decades of near silence, several papers have been published in the last few months, all from different authors but with unusual similarities [24]. Perhaps a self-appointed "data-sleuth," with a natural talent for identifying image manipulation, working alone or in a loose collegiate network of like-minded, often-anonymous colleagues, spots a photoshopped image in a published paper [3,25]. They follow through with scrutiny of images in other editions of the journal and identify a recurring theme. They contact the journal editor directly, alerting them to the problem, or they place notices on PubPeer [49].

The editor or editor-in-chief knows about individual research misconduct but also knows that some academics like to criticize their rivals' papers, occasionally with malign intentions. They may have never heard of paper mills. They may dismiss the matter as a frivolous concern or unfounded attempt at slander. If sufficiently concerned, they may email the in-house Research Integrity team.

The team examines the target paper(s) and logs the suspicious manuscripts with a tracking number. They advise, guide, and support the editor-in-chief throughout the investigation. The editor reads the problematic manuscript(s) carefully, looking for other signs of misconduct or fraud. They look at the particulars of the manuscript submission(s) process and reread the cover letter(s). They check the peer review process to confirm whether the reviews seem legitimate. They contact the corresponding author(s) requesting an explanation of image concerns or data discrepancies; possibly they ask for raw data. At the same time, suspecting that this collection of problematic papers could be related to paper mill activity rather than individual author misconduct, the editor and supporting team might examine linked papers [1]: all publications or manuscripts under submission from each of the authors [2]; all manuscripts reviewed by the target paper(s) peer reviewers [3]; similar publications in the same journal, found through

Table 3. Strategies to prevent and detect paper mill activity; example references [3,50]

Publishers

- Upskill journal editors and editorial staff on paper mill activity and how to identify it before publication
- Encourage all publishers to review policies and practices with particular attention to known vulnerabilities for paper mills (eg, use of author-recommended reviewers; allowing new authors to be added after submission)
- Continue to develop and share automated tools that screen for submission anomalies/patterns, duplicate manuscript submissions, tortured phrases, manipulated images, signs of artificial intelligence activity, suspicious citation activity. For example, Wiley's Papermill Detection tools [56]; STM's Integrity Hub resources (stm-assoc.org/stm-integrity-hub/)
- Increased Editorial support from specialist research integrity teams for investigation of and advice on handling suspected paper mills
- Expand use of open peer review
- Mandate raw data submission
- Mandate posting of original manuscripts as preprints
- Accelerate and scale postpublication corrections

Researchers and readers

- Share knowledge to increase awareness of paper mills
- How mill products and targeted journals may be evolving
- Consider paper mills before attempting to reproduce published experiments
- Use our watchdogs and their freely available tools
- Retraction Watch (retractionwatch.com), PubPeer (pubpeer.com), Problematic paper screener [57], Seek & Blastn [34]

Institutions

- Include paper mill information in student and researcher education on publication integrity, research misconduct
- Change research incentives to reduce pressures to publish
- Encourage use of open science practices
- Preprint servers, making raw data and code freely available
- Require publications in journals with commitments to open science practices, timely postpublication corrections

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similarities in key words, title, topic, format [4]; unrelated citations in the reference list of the target paper.

Screening of all these papers begins. (See Table 2; some of these criteria would also apply to "one-off" fraudulent papers outside of the paper mill setting). Some activities can only be done by publishing staff with "back-end" information about submission and peer review processes. Others are accessible to any reader. Typically, a paper mill product will contain multiple anomalies. Screening and following up on the target paper(s) and related papers can take years [3]. During the process, the journal may issue a comment (often called an editor's Note) alerting the reader to concerns and ongoing investigations into the paper. This temporary online note appears on the journal's webpage with the HTML version of the publication but is not indexed, so readers accessing the paper through

indexing services will not see it. As the investigation progresses, the journal may issue a new comment (perhaps called an Expression of Concern) and this may be indexed with its own doi, making it more likely that readers will see it. Once paper mill activity is confirmed, the journal will retract the paper(s) and issue a Retraction Notice: a permanent document with its own doi, preferably not the same one as the retracted paper, indexed and linked so that it appears every time a reader accesses the paper through any online service.

6. Problems, challenges, barriers

Detection and management of paper mill products does not always progress as described above. There are many challenges and barriers. First, some journals and publishers are insufficiently resourced: editors are not adequately trained, support services from the publisher are limited or absent, there is limited interest or capacity for investigation of suspected mill activity [46]. Second, paper mills are constantly adapting, learning from past mistakes and making use of new technologies including artificial intelligence tools to generate fake images and text that are harder to detect [54]. Third, publishers are competitive, commercial entities: those with an in-house detection program may not wish to share, seeking the competitive advantage that proprietary tools may deliver. Fourth, publishers considering the sharing of information (such as names of black-listed authors, peer reviewers, IP addresses) may be deterred by their legal advisors based on concerns about authors' legal rights to privacy [3]. Fifth, publishers may fear the reputational damage that comes with publicity around large-scale retractions. Nevertheless, some big publishers have taken a strong stance against paper mills. As noted above, Wiley retracted thousands of papers from its subsidiary Hindawi in 2023 and reports it is planning to stop using the beleaguered Hindawi name in 2024 [1].

7. How can we get the trust back?

High-profile news articles about paper mills [55] are important for alerting readers to the problem but they may also foster mistrust of academic publications. There are many suggestions for how publishers, researchers and academic institutions can act to prevent and manage paper mill activity (see Table 3). Artificial intelligence is likely to be part of the solution, with enthusiasm for new automated tools that can screen submission practices and manuscripts for signs of paper mill activity.

Sharing of experiences, ideas, and tools will be important [58]. Many journals have already shared their own experiences with paper mills [8]. COPE and STM already facilitate conversations among publishing staff about detecting, investigating and managing paper mill products.

Ad hoc committees have come together to discuss standardized practices and processes, for example, the National Information Standards Organisation convened a working group to deliver guidance on how to manage the metadata of editors Notes and Retractions [59]. The new United2Act group (united2act.org) aims to connect publishers with data sleuths/researchers and research institutions to foster conversations and collaborative research into how paper mill activity can be prevented and managed. Perhaps the single most important response will be to appropriately scale and accelerate the flagging and retraction of paper mill products, both as a deterrent and to protect researchers and scholars.

8. Closing thoughts

Paper mills threaten to make a mockery of a publishing industry that has built its reputation on the production of trustworthy academic papers and of indexing services that aim to curate high-quality papers. If these industries were to fail, readers would experience greater reliance on unvetted papers, with less guidance to distinguish between trustworthy research and bogus studies. We continue to believe in the importance of research and the publication of reliable outputs. We are optimistic about the future of academic publishing but welcome ongoing conversations about systemic change to reduce the focus on publication numbers and decrease consumer interest in paper mill outputs. In the meantime, we encourage publishers and academic institutions to invest in education and research to increase awareness about paper mill activity and improve tools that prevent publication of their products.

CRediT authorship contribution statement

Lisa Parker: Writing − original draft, Conceptualization. **Stephanie Boughton:** Writing − review & editing. **Lisa Bero:** Writing − review & editing. **Jennifer A. Byrne:** Writing − review & editing, Funding acquisition, Conceptualization.

Declaration of competing interest

S.B. is a freelance Research Integrity Specialist and has provided consultancy work for Springer Nature and Cochrane. She was previously employed by Cochrane. There are no competing interests for any other author.

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Data availability

No data was used for the research described in the article.

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