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The Role and Challenges of Academia in the Marine Natural Products Pipeline

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Abstract

Despite academia's central role in discovering marine natural products (MNPs), many promising compounds fail to advance toward commercialization due to persistent barriers such as limited funding, evolving regulations, and constraints on capacity and compound supply. This study documents the barriers academic stakeholders encountered in six selected MNP projects (see Table 2 for selection criteria), which barriers recur, and characterizes the decisions that led to these barriers. It then assesses the forms of value these projects realized and determined where targeted intervention could best support the academic contribution to the pipeline. A narrative literature review informed the study design, sampling strategy, and interview guide. Using a stakeholder perspective, semi-structured interviews were conducted with participants from six selected MNP projects, and thematic analysis of 16 transcripts was performed using a modified QUAGOL method implemented in NVivo. By reconstructing projects that had halted, rather than surveying active research work, the study examines barriers at the point each project stopped. The analysis revealed five major themes, from which twenty-nine barrier codes were organized, eleven of which recurred across 3 or more of the six projects. Key challenges include funding constraints that narrow research scope, regulatory complexity surrounding access and benefit sharing, loss of specialist expertise across generations, and misaligned performance metrics between academia and industry. These enduring obstacles, many unchanged from studies conducted a decade ago, underline the need for targeted, sustained intervention. Interventions proposed, including resource reallocation mechanisms within funded consortia, regulatory training for researchers, and structured knowledge preservation initiatives, offer a starting point for improving pipeline efficiency and the market readiness of marine-derived products.

Keywords: marine bioactive products, marine genetic resources, marine biodiscovery, drug discovery pipeline, academia to industry translation, stakeholder perspectives

1 Introduction

Only a small fraction of marine natural products reaches commercialization, particularly in the pharmaceutical sector. Most halt at some point in the pipeline. What happened at the point they stopped, and why, is rarely recorded. Academic stakeholders carry out much of the earlier work in this pipeline, so where their work stalls shapes what reaches society. Institutional laboratories across disciplines serve as discovery hubs, allowing researchers to develop novel methodologies and drive the early stages of the product development pipeline through innovation of techniques, tools, and protocols. However, their level of success, whether measured by tangible output of inventions/developments or overall knowledge gained, is impacted by external and internal factors (El Kadiri Boutchich 2020). Further examination into these factors during the literature review emphasized four main categories that impact success, regardless of discipline (**Table 1**). These four categories orient why academic capacity and contribution matter to the pipeline. They frame the motivation for this study, but not the analysis. The barriers reported later in this paper are built from what participants reported, and not necessarily sorted into these four categories.

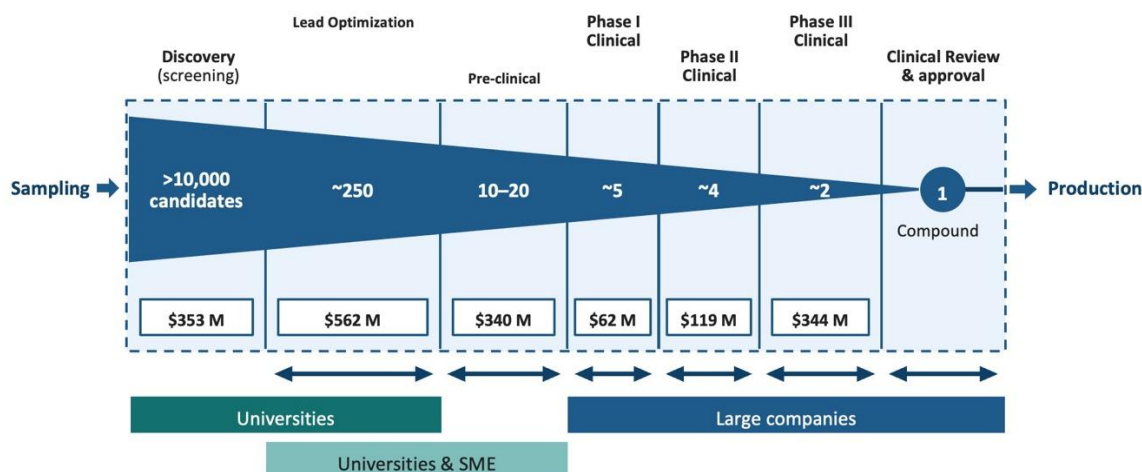
Table 1. Academic Factors Influencing Academic Research Lab Success Across Disciplines

Factors	Implication	Sources
Access to Resources	Access ¹ to resources amplifies research potential	(Brownson et al. 2017; Huenneke et al. 2017; Fecher et al. 2021)
Funding	Funding enables research endeavors	(Heyard and Hottenrott 2021; O’Kane et al. 2023; Thelwall et al. 2023)
Research Environment	Supportive environments nurture human resources	(Aladejana and Aderibigbe 2007; Muscio et al. 2022)
Collaboration & Networks	Collaboration fuels innovation, enriching research outcomes	(Fernandes et al. 2021; Xiao and Prompanyo 2021; Liu and Lin 2024)

As the success of academic research labs across various disciplines is influenced by a multitude of factors, these factors will also consequentially impact the broader scientific landscape. Academic research provides the foundational advancements for many fields, such as pharmaceutical discovery. The transition from academic research to practical application in drug discovery is a natural progression, as academics contribute substantially to the early stages of the drug discovery pipeline

¹ Capacity here refers to the people, skills, infrastructure, and funding available to carry out and sustain research. Two specific senses appear later: laboratory capacity (the resources to do the bench work) and translational capacity (the capability to move a compound from discovery toward development and all that entails).

62 (Silber 2010). As seen in **Fig. 1**, universities contribute to the first ~50% of the pipeline, with the first
 63 ~15% of the pipeline being almost solely their domain in terms of screening and optimization.



64

65 **Figure 1.** Pharmaceutical Discovery Pipeline (adapted from Marcel Jaspars). Compound numbers
 66 and cost per phase from Paul et al (Paul et al. 2010). Costs are capitalized cost per launch, and are
 67 therefore larger than the cost of an individual study at that phase, as seen in Sertkaya et al. (Sertkaya
 68 et al. 2016). Subsequent reviews report a wide range of per-drug research and development estimates
 69 depending on method and inclusion criteria, and reported clinical failure rates have seen a rise
 70 (Rennane et al. 2021; Sun et al. 2024).

71 Based upon this contribution, it is a natural conclusion that improvement of the academic research
 72 success rate will serve as a catalyst for improved outcomes within the pharmaceutical pipeline. This
 73 is particularly evident for marine natural products (MNPs), of which more than 45,000 have now
 74 been described (Lyu et al. 2021; Carroll et al. 2022, 2023, 2024, 2025, 2026).

75 Natural products and their derivatives have accounted for a substantial proportion of the small-
 76 molecule drugs approved over the past four decades (Newman and Cragg 2020). Within that source
 77 class, the exploration of marine biodiversity has opened a distinct avenue for drug discovery. In
 78 practice, academic institutes in the natural product space may prioritize pharmaceutical discovery
 79 over other bioactive applications (i.e., cosmeceutical, nutraceutical, and agrochemical use),
 80 potentially driven by funding incentives and research project parameters. Marine natural product
 81 research is strongly represented in pharmaceutical drug discovery, in addition to its role in the
 82 nutraceutical, industrial biotech, and agricultural fields (Martins et al. 2014). Marine organisms, such
 83 as sponges, fish, and various microorganisms, produce bioactive compounds with potential
 84 pharmaceutical applications. Further, compounds derived from MNPs have had an ~4x higher
 85 success rate than other natural product (NPs) compounds.

86 As of July 2026, 19 marine-derived pharmaceuticals have been approved for clinical use, most of
 87 them in oncology (Marine Pharmacology 2026a). The projects examined here were carried through
 88 early discovery almost entirely by academic and public-sector groups, consistent with the wider
 89 public-sector contribution to drug and vaccine discovery (Stevens et al. 2011). Sustained public
 90 investment supports that contribution, in the settings where it has been quantified (Galkina Cleary et
 91 al. 2018; Nayak et al. 2019).

92 Market analyses of marine biotechnology report a positive growth, but identify commercialization
93 steps as the persistent constraint(Daniotti and Re 2021). Further, they find the technologies closest to
94 market concentrated in food and nutraceutical rather than pharmaceutical applications. Industry
95 projections place the global market for marine derived drugs at approximately USD 4.5 billion in
96 2026, forecast to reach USD 10 billion by 2036(Future Market Insights 2026). Such forecasts are
97 commercial estimates, and not peer-reviewed findings.

98 Most research on marine biotechnology barriers looks at the innovation that continued to advance in
99 the pipeline. Stakeholder surveys reach companies still in business, and researchers still working in
100 the field(Amirkia and Heinrich 2015; Collins et al. 2020). However, they take the researcher or the
101 firm as the unit of analysis, capturing a perspective that is generalized across a career, rather than tied
102 to a specific compound that halted in the pipeline. Reviews of academic drug discovery describe the
103 problems that active research groups run into; reviews of marine natural product commercialization
104 set out the barriers documented in published literature; productivity studies measure how the field is
105 doing as a whole (Martins et al. 2014; Parrish et al. 2019; Pereira 2019; Hopkins et al. 2025;
106 Stremlau and Slusher 2025). Interview studies in academic drug discovery focus on the directors of
107 programs(Parrish et al. 2019). Specific projects that stopped are rarely examined up close, using the
108 accounts scientists in the lab conducting the day-to-day work.

109 In this study, the unit of analysis is the halted project. It follows six marine natural product projects to
110 the point at which each one halted and asks the researchers who worked on them what caused the
111 halt. From that perspective, a single halted project can reveal root causes that run throughout the
112 marine pharmaceutical pipeline. Studies and literature reviews of still-active groups and firms cannot
113 explain why a specific project failed. What stopped a project is not often recorded in the literature,
114 and only the people involved can account for it. The six projects examined in this study reveal the
115 barriers and decisions that end MNP projects, and the value those projects produced despite these.

116 This study is confined to the human therapeutic pathway, where the barriers are toughest, the
117 timelines longest, and the route for marine natural products best-documented(Zamani et al. 2025).
118 Turning a marine compound into a medicine is a long, costly, and heavily regulated process, often
119 two decades or more (Rijo et al. 2025). Nutraceutical, cosmetic, food and agricultural products reach
120 market through shorter routes with fewer barriers(Daniotti and Re 2021). Therefore, they do not face
121 the same prolonged translation gap, though they face their own set of barriers. All six projects
122 examined here were pharmaceutical, spanning discovery through preclinical development.

123 Given academia's significant contribution to the early stages of the drug discovery pipeline, and the
124 forecasted expanded market presence of marine-derived drugs, it is essential to analyse the current
125 challenges and roles of these stakeholders. Such an analysis can help unlock their full potential to
126 improve public health outcomes, by enabling and enhancing the development and application of
127 novel marine compounds for disease treatment.

128 The objectives of this study are to:

- 129 1. Document the barriers academic and affiliated researchers encounter in marine natural
- 130 product projects and establish which recur across projects
- 131 2. Characterize how participants account for the decisions that stopped or redirected
- 132 work, and the mechanisms and consequences involved
- 133 3. Assess which forms of value these projects realize and how far along the pipeline that
- 134 value realization occurs

4. Identify where intervention could be directed, and propose targeted interventions

Addressing these objectives requires reconstructing each project from the people who worked on it, which the following sections set out.

2 Materials and Methods

This research was conducted in collaboration with the Marine Biodiscovery Centre at the University of Aberdeen, under the supervision of Prof. Marcel Jaspars. Our approach combined a narrative literature review, adaptation of a MNP commercialization pipeline, and a qualitative interview study analyzed thematically. This mixed methods approach aimed to maintain continuity from background framing to empirical analysis.

Assistive software, including AI tools, was used for language, formatting, and layout only. No data, results, or image content were generated by AI. The authors are fully accountable for the final content.

2.0 Literature Review

A narrative literature review was conducted in MarinLit and PubChem, using key search terms ‘academic laboratories + impact + factors’ and ‘marine natural product + pipeline.’ This was an orienting, non-comprehensive narrative review used to guide the study design, not a definitive or up-to-date mapping of the field. This literature review is summarized within the introduction of this study, as well as being used as a guideline for outlining the objectives of the case study and consequentially selecting projects and corresponding interviewees.

2.1 MNP Pharmaceutical Pipeline Construction

The revised pipeline (Figure 3) was developed iteratively in discussion with researchers active in the marine natural product field, as well as the general drug discovery field. These discussions included several of the study’s interview participants, together with informal conversations with other researchers, for example at conferences. Upon conclusion of the study, interview data was used to validate this pipeline. This revised pipeline served as a conceptual framework for understanding the academic perspective of MNP pipeline progression. To complement this conceptual framework, a quantitative version of the MNP pharmaceutical pipeline was developed aiming to align commercial and academic perspectives, as well as estimate number of compounds progressed through each stage of the pipeline from 1960-2026 (**Fig. 4**).

The quantitative estimates draw on publicly available databases and published review series, and because their reference periods and definitions differ, the values are read as magnitudes rather than as stage-to-stage conversion rates. The discovery (screened) stage combines the Collection of Marine Natural Products Database (CMNPD), which lists 31,561 compounds to the end of 2019, with the annual Marine Natural Products review reports of Carroll et al. in Natural Product Reports, which add ~6,700 further compounds for 2020 to 2024. MarinLit (Royal Society of Chemistry), the continuously updated MNP database, records 45,009 compounds as of 25 September 2026 (Royal Society of Chemistry 2026). The hits (active compounds) stage uses the MarinLit’s compound-bioactivity records, from its Biological activity (any) filter (29,714 compounds, accessed 25 September 2026), which have not been updated since and for which no comparably structured bioactivity annotation is available for later years. The lead and preclinical-candidate stages are reported as not estimable, because no source reports them in a form consistent with this table's

definitions. For example, the marine pharmacology review series counts every compound with any reported activity. That is a broad measure. It captures all active compounds, not only those formally nominated as development candidates. Nominating a preclinical candidate requires further work (i.e., in vivo testing, ADME, toxicology) that these activity counts do not reflect. Such compounds therefore sit at the hits stage, and not the lead or preclinical candidate stage, in the tables and figures constructed for this study. From development candidates stage and onward, the figures were reconstructed cumulatively from the maintained Marine Pharmacology clinical pipeline (including its preclinical review series and archived snapshots)(Marine Pharmacology 2026b).

2.2 Interview Study

2.2.1 Selection of Participants

Participants were selected from relevant projects in which MNPs were developed by academia. For the purpose of this study, projects are defined as research teams collaborating upon development of a specific compound(s) isolated from a marine organism. Projects (pseudonymized as projects A-F), and their corresponding teams, were included where an academic group had developed a MNP that later halted or was significantly challenged. The full inclusion criteria for interviewees are given in **Table 2**. In total, six projects met the criteria and 16 interviews were completed, providing coverage across stakeholder roles and the point of the pipeline at which the project halted.

Table 2. Inclusion Criteria to select projects for stakeholder interviews

Inclusion Criteria	Further Explanation
Project originated from academia	Exclusion of products in the pipeline with no input from academia
Project was halted or significantly challenged ² prior to commercialization in the pipeline (Fig. 3)	Exclusion of successfully marketed products
Project incorporated collaboration with external entities	Exclusion of internalized projects, to better capture varying perspectives and stakeholder groups

Based on these criteria, selection of the resultant six projects occurred through two approaches. The primary approach relied upon expert collaboration and targeted selection based upon the expertise of those who have operated within the field over a significant timespan. The secondary approach utilized narrative literature review to follow the story of a compound and determine the halted point within the pipeline, such as to incorporate a well-rounded representation of the pipeline within the

² Selecting only projects that halted before commercialization introduces a deliberate negative-case, or deviant-case, sampling design(Patton 2010). This is methodologically aligned with the aim of identifying stage-specific barriers, which projects still in progress cannot reveal, and is stated explicitly here to avoid any impression of selective exclusion.

study. Further inclusion criteria of the participants were based upon their listing as an author of the publication(s) attached to the compound in question.

2.2.2 Data Collection

Once inclusion criteria were confirmed, stakeholders were contacted via email by the primary researcher. Follow-up emails were sent up to three times if no initial response was received. There were potential interviewees who did not respond to the invitation. As a result, certain research projects initially identified as potential cases were not included in the study.

Interviews were then conducted in English via either the Microsoft Teams or Zoom platforms, based upon the preference of the interviewee. Participation consent forms were acquired and stored securely according to GDPR guidelines. Each interview was recorded and stored on a local hard drive. The primary researcher then transcribed and pseudonymized the interview and shared it with the interviewee via email. The interviewee was then allowed to edit or strike any aspect of the interview before granting transcription approval. Recordings of interviews were then deleted from the local hard drive.

The studies involving human participants were reviewed and approved by the University of Aberdeen (Ref. 1423752, 8 November 2023) and conducted in accordance with the Declaration of Helsinki. The participants provided their informed consent to participate in this study. This article does not contain any studies with animals performed by any of the authors.

2.2.3 Thematic Analysis

The approved and pseudonymized transcripts were then imported into NVivo for thematic analysis. The approach was codebook thematic analysis, one of the three types of thematic analyses identified by Braun and Clarke, which combines the qualitative research values of thematic analysis with a fixed and documented codebook (Braun and Clarke 2021). Following the method outlined by Braun and Clarke, the codebook is used to organize and develop the analysis, not to test whether coding was reliable or accurate. It is not reflexive thematic analysis. The codebook is structured as a three-level hierarchy of five overarching themes, their subthemes, and final codes. Reference counts are reported at the code level and aggregated up into themes. The terms *theme* and *code* are used in this sense throughout.

Thematic analysis followed a modified **Qualitative Analysis Guide of Leuven (QUAGOL) method**, using NVivo as the implementation tool, with steps outlined in **Fig. 2** (Dierckx de Casterlé et al. 2012). Thorough preparation of the coding process was done in collaboration with dr. Teodora Lalova Spinks (herein after, ‘secondary reader (TS)’), to ensure integrity and lack of bias.

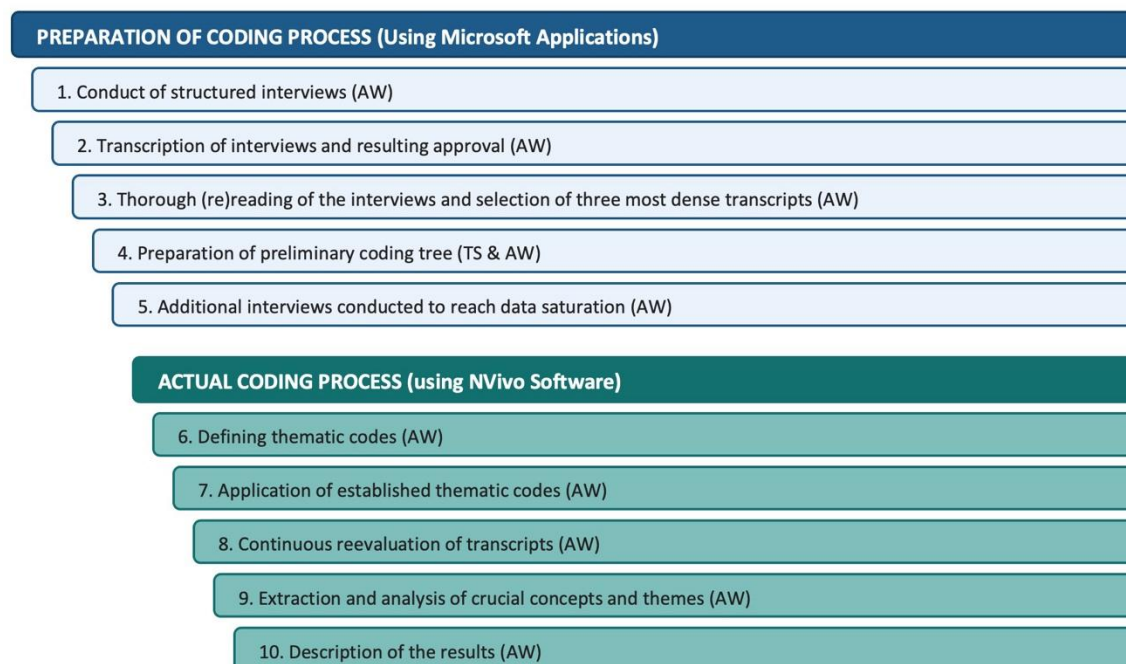


Figure 2. Modified Qualitative Analysis Guide of Leuven (QUAGOL) stages implemented in this case study

¹ *adapted from Dierckx de Casterlé et al., 2012 (Dierckx de Casterlé et al. 2012)*³

Active analysis procedure entailed continuous engagement between researchers throughout the coding phase to ensure developing thematic accuracy as new insights emerged. Each researcher analyzed three transcriptions, chosen based on their density of content, to establish meaningful themes prevalent to the comprehensive study. Comparison and open discussion with the secondary researcher were then conducted in order to create a hierarchical organization (coding tree). This code tree was then imported into NVivo for application to remaining transcripts. The coding frame was therefore built from the data rather than imposed from a prior framework. The coding cycle is inductive in construction, deductive in application, and iterative in revision. It proceeded throughout the cycle by constant comparison, which is one of the three strategies the authors of QUAGOL name as a defining quality of the guide (Dierckx de Casterlé et al. 2012). Additional interviews were conducted, based upon creating a comprehensive view of issues through incorporation of additional projects, as well as ensuring data saturation between individual transcripts. Projects were strategically selected to represent each stage of the pipeline and interviews were conducted until the point of data saturation⁴ (Fig. 5). Data saturation within this study refers to the point at which no new codes were needed to fully analyze the transcripts. Data saturation was determined by sequential comparative

³ Clarification on “modified”: Analysis followed the stages in Fig. 2, with the coding frame built and revised in collaboration with the secondary reader as coding proceeded. Two adaptations are noted. The hierarchical tree was drawn up after the first transcripts rather than after the within-case stages had been completed for every case, though it remained open and codes continued to be added by agreement as analysis continued (see section on reaching saturation). A later pass by the first author then revised code labels and reorganised the frame, leaving the coding decisions themselves substantially unchanged. Both are consistent with the constant comparison that the QUAGOL guide names as one of its defining strategies.

⁴ In this context, data saturation implies no novel themes emerged from the analysis

252 analysis of code references applied to transcripts within NVivo to verify lack of emergence of new
253 theme.

254 As a constant comparison process, over the course of the following weeks, transcripts were revisited
255 critically to determine if any additional codes needed to be incorporated within the established tree,
256 until data saturation was reached. Each added code involved collaboration with the secondary
257 researcher, in order to maintain an unbiased perspective. Having finalized the coding tree, each
258 applied code was then defined. A final revision of the thematically coded interviews then confirmed
259 that the phrasing of the corresponding definitions applied to each relevant coded section.

260 Extraction and analysis were then conducted, with outputs being incorporated in the **Results** section.
261 Participants were charted against codes in a matrix of cases by codes, so that the views of each
262 participant remain connected to other aspects of their role and perspective, while comparison across
263 cases (projects) is still possible. This follows the charting stage of the Framework Method(Gale et al.
264 2013). Codes were organized by both overarching themes, as well as color coded by frequency of
265 their mention. This provided a visual representation of the most prevalent issues and academia's
266 involvement. Following this initial analysis, challenges recurring across three or more of the six
267 traced projects were carried forward to the discussion of interventions(Gale et al. 2013). This allows
268 a narrowing of scope in terms of applicable interventions to the most common obstacles faced by
269 academics within the field, for further discussion. Where numbers are given, they describe this set of
270 interviews and nothing beyond it. They are there to make words like "most" and "only one" more
271 precise, and to show where something was raised by no one. They are not a basis for generalizing,
272 because participants in this study were chosen based on specific characteristics of a project, rather
273 than sampled to represent a wider population.

274 Passages in which a participant speculated about a project they did not participate in were excluded
275 as proxy accounts. Passages recounting work the participant had personally witnessed or contributed
276 to were retained, even where that work concerned compounds other than the one(s) in the project that
277 was targeted for this study.

278 The reference counts were known at the time the attribution rule was chosen. The stakeholder-group
279 counts in Table 3 include a secondary affiliation in cases where a participant belonged to two
280 stakeholder groups (6/16 participants). A blank secondary affiliation indicates they did not have a
281 secondary role.

282 Furthest Stage Evidenced records the furthest translational stage for which public record evidence
283 (i.e., publications, patents) was found as of July 2026. This is ordered as *publication only*, *patenting*,
284 and *clinical development*. A lower value records the limit of what was public evidence for that
285 project and cannot be seen as concrete proof that no further activity occurred. Because the public
286 record often thins between the bench and the market, the furthest evidenced stage marks a floor rather
287 than a ceiling and is not strictly comparable across projects. Option value⁵, the value of holding open
288 the possibility of future development (Section 3.0.7) was coded from each project's own patent
289 record, using the final status of its earliest patent filing. Each project was placed in one of three

⁵ Option value is coded from the patent record because a granted right that is maintained or run to term is the clearest documentary proxy for transferable, still-exercisable value a project created. Further, its terminal disposition (held, relinquished, or never filed) is a matter of public legal record rather than researcher judgment.

states: the filing was granted and kept in force or run to term, it was filed and then given up before term, or nothing was ever filed. This reflects documented legal status only.

3 Results

A total of 16 interviews were conducted to gain stakeholder perspectives on the challenges they face in bringing a MNP from the hands of academics to the market. Relevant background characteristics of stakeholders, such as expertise, position held at time of project, geographical location, and decade of each project are further described in **Table 3**. Some participants held more than one stakeholder role. Further, because every included project involved collaboration with external entities (Table 2), the sample spans academic, industrial, and government or public-research perspectives rather than academic voices alone.

Table 3. Descriptive characteristics of interviewed stakeholders

Project ⁶	Halt Stage ⁷	# Interviews	Decade	Location	Stakeholder Group ⁸	Expertise
<i>E</i>	Leads	1	1990–2000	USA (1)	Academic (1), Government/public research (1)	Chemistry (1)
<i>C</i>	Leads	3	2010–2020	Australia (3)	Academic (3), Collector/field supplier (1)	Chemistry (2), Biology (1)
<i>A</i>	Preclinical Candidates	4	2010–2020	UK (2), Europe (2)	Academic (3), Non-profit foundation (1)	Chemistry (3), Biology (1)
<i>B</i>	Preclinical Candidates	3	2010–2020	USA (3)	Academic (3), Government/public research (1)	Chemistry (3)
<i>D</i>	Development Candidates	3	2000–2010	USA (3)	Academic (2), Industrial (2), Collector/field supplier (1)	Chemistry (2), Biology (1)
<i>F</i>	Development Candidates	2	2000–2010	USA (2)	Government/public research (2), Collector/field supplier (1)	Biology (2)

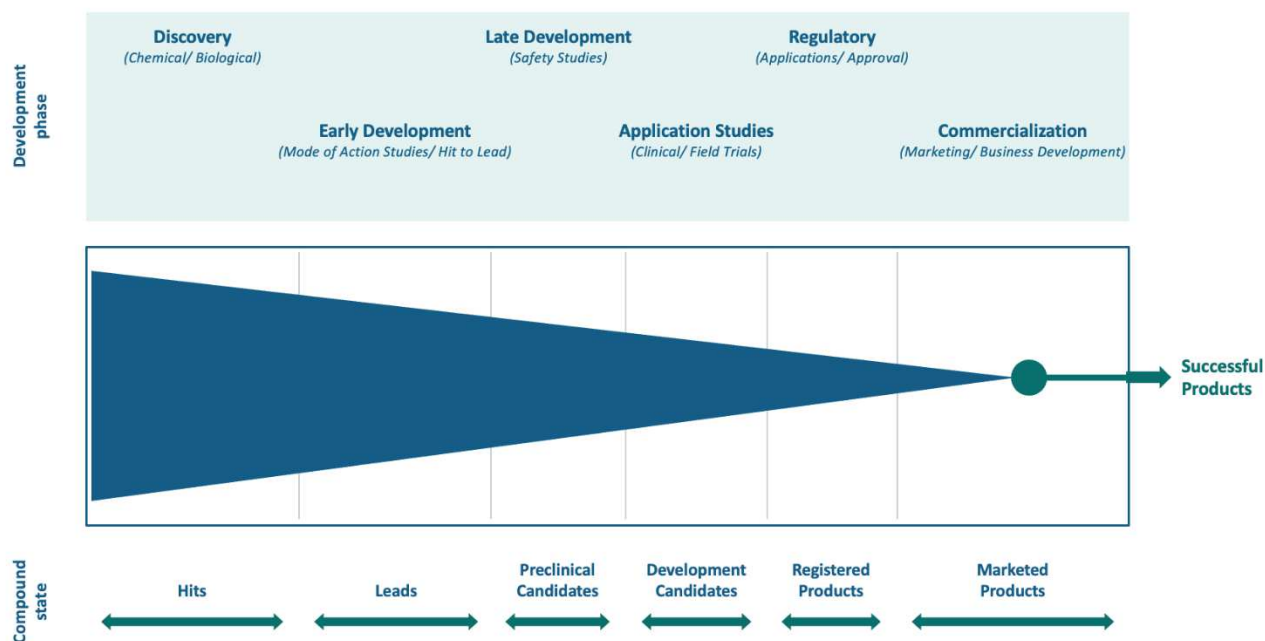
Priority was given to incorporating projects that represented failures at all points of the pipeline relevant to the academic field, ensuring subsequent analysis of stage-specific challenges (**Table 3**). Stage definitions follow standard drug-discovery terminology (Hughes et al. 2011; Deore et al. 2019). A hit is a compound showing reproducible activity above a set threshold in a primary screen. A lead is a confirmed, characterized hit selected for optimization. A preclinical candidate is an optimized lead that has passed in vitro and in vivo safety, ADM and pharmacokinetic assessment, and is ready for Investigational New Drug (IND) studies. Finally, a development (clinical) candidate

⁶ Projects are ordered by the compound state each reached, not alphabetically. Compared to the prior figures, no project in this sample halted at Discovery (Screened) or Hits (Active Compounds). That cell is absent rather than empty because the row would carry no case. Table 2's inclusion criteria do not exclude a project halting there, so this is a sampling zero rather than a structural one.

⁷ Halt stage is the furthest compound state the academic project reached, taken from literature review of each project, and reflecting the furthest progress of the project including work carried forward by collaborating groups. Stage names follow Table 4.

⁸ Please note that some experts represent multiple stakeholder groups, based on past and current professional roles.

309 is a compound cleared to enter human trials. The boundaries between these stages are not sharply
310 defined in the literature, so are applied here based upon feedback from the individual interviews.



311
312 **Figure 3.** MNP Pipeline Developed in Collaboration with Scientific Stakeholders

313 Figure 3 illustrates the MNP pipeline from the scientific stakeholder perspective. It differs from the
314 pharmaceutical development pipeline in Figure 1 in both terminology and granularity. Figure 1 uses
315 standard drug-development phase terminology (discovery, preclinical, and clinical phases) together
316 with per-phase compound numbers and costs, whereas the stakeholder-derived pipeline adds more
317 specific intermediate compound states coming from the academic workflow. Figure 1 and the
318 development-phase band along the top of Figure 3 describe development phases (usually used by
319 industry), while the compound-state row along the bottom of Figure 3 describes advancement of the
320 molecule (usually the terms used by academics). describe properties of a molecule. Each
321 development phase sits directly above the compound state it yields, so the two read as one aligned

pipeline. The two are complementary rather than alternative versions of the same pipeline, reflecting the finer distinctions scientific stakeholders draw within their day-to-day work.

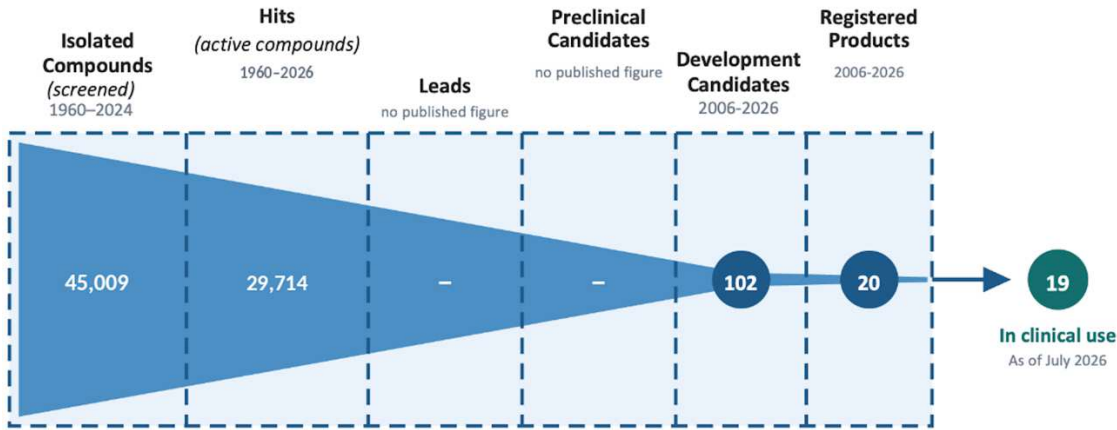


Figure 4. Quantitative MNP Pipeline (1960-2026)⁹.

Figure 4 and the accompanying table (Table 4) account for the space from 1960-2026 using available data. The rows carry different reference periods, stated in each case, and are intended to demonstrate magnitude of each stage rather than the full conversion rate, as it is likely that some numbers are missing from this recount based on the materials available. This model reflects the progression of a MNP from initial compound discovery to successful drug registration. These figures describe the marine pharmaceutical pipeline overall. The six interviewed projects that follow are individual cases that have occurred within the pipeline.

Table 4. Estimated Compound Numbers Across MNP Pharmaceutical Pipeline. Reference periods differ by row and are not converted into stage to stage rates (percentages).¹⁰

Stage	Original Estimate	Reference period	Rationale for Estimation
Discovery (Screened)	~45,009	1960-2026	Total marine natural products recorded in MarinLit, the continuously updated NP database, accessed 25 September 2026 (Royal Society of Chemistry 2026).
Hits (Active Compounds)	29,714	1960-2026	MarinLit compounds with any recorded bioactivity (Biological activity (any) filter), accessed 25 September 2026.
Leads	Not estimable	-	Difficulty ascertaining this value among literature. Back calculation approach yielded unrealistic values.
Preclinical Candidates	Not estimable		No source reports this quantity. The marine pharmacology review series counts compounds for specific target, which is a flow and does not require in vivo work, ADME, toxicology or candidate nomination(Mayer et al. 2024, 2026). Therefore, those compounds sit at the Hits stage on this table's definitions. CMNPD stops at

⁹ The Phase II and Phase III cohorts span 2006-2026 and the current-development count is as of July 2026. “Registered Products” carries both the cumulative figure ever approved (20) and the number approved for clinical use of July 2026 (19).

¹⁰ Pharmaceutical sector only; compounds reaching cosmetic, nutraceutical, agrochemical, reagent or other markets are not counted.

			reported bioactivity and the clinical pipeline listing begins at Phase I.
Development Candidates	102	2006-2026	Cumulative reconstruction from the maintained marine pharmacology clinical pipeline and its predecessor, across archived snapshots from 2 September 2006, when the site was first archived (Marine Pharmacology 2026b).
Of which reached Phase II or beyond	66	2006-2026	See above
Of which reached Phase III or beyond	33	2006-2026	See above
Currently in clinical development	26	July 2026	See above
Ever approved	20	2006-2026	See above. Note that there may be more that were approved and withdrawn, but these could not be located from the current or archived versions of the marine pharmacology website.
Currently approved for clinical use	19	July 2026	See above

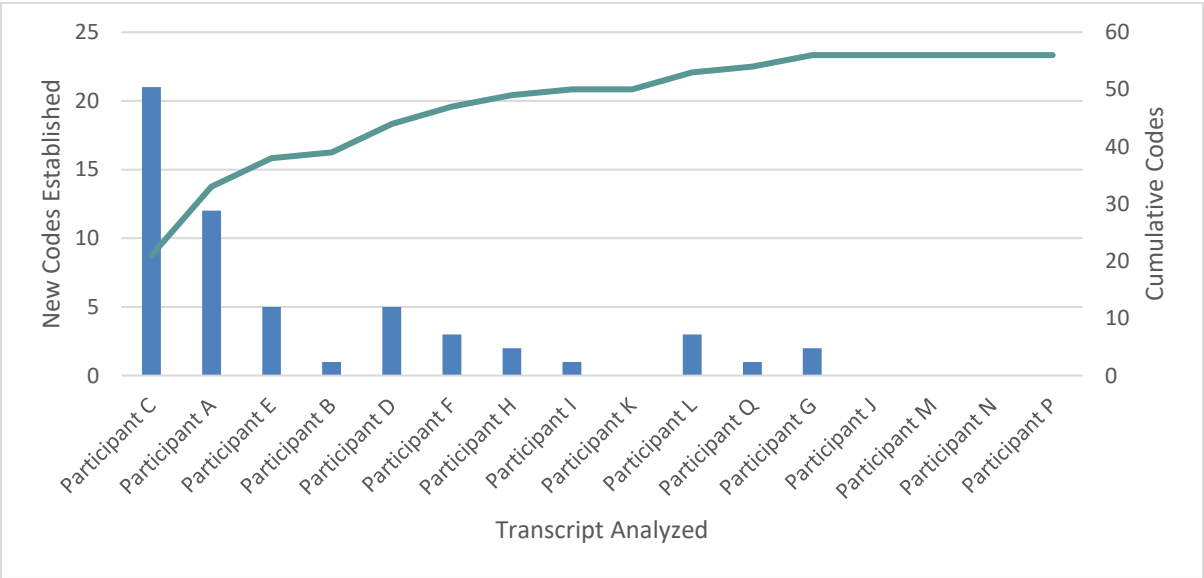
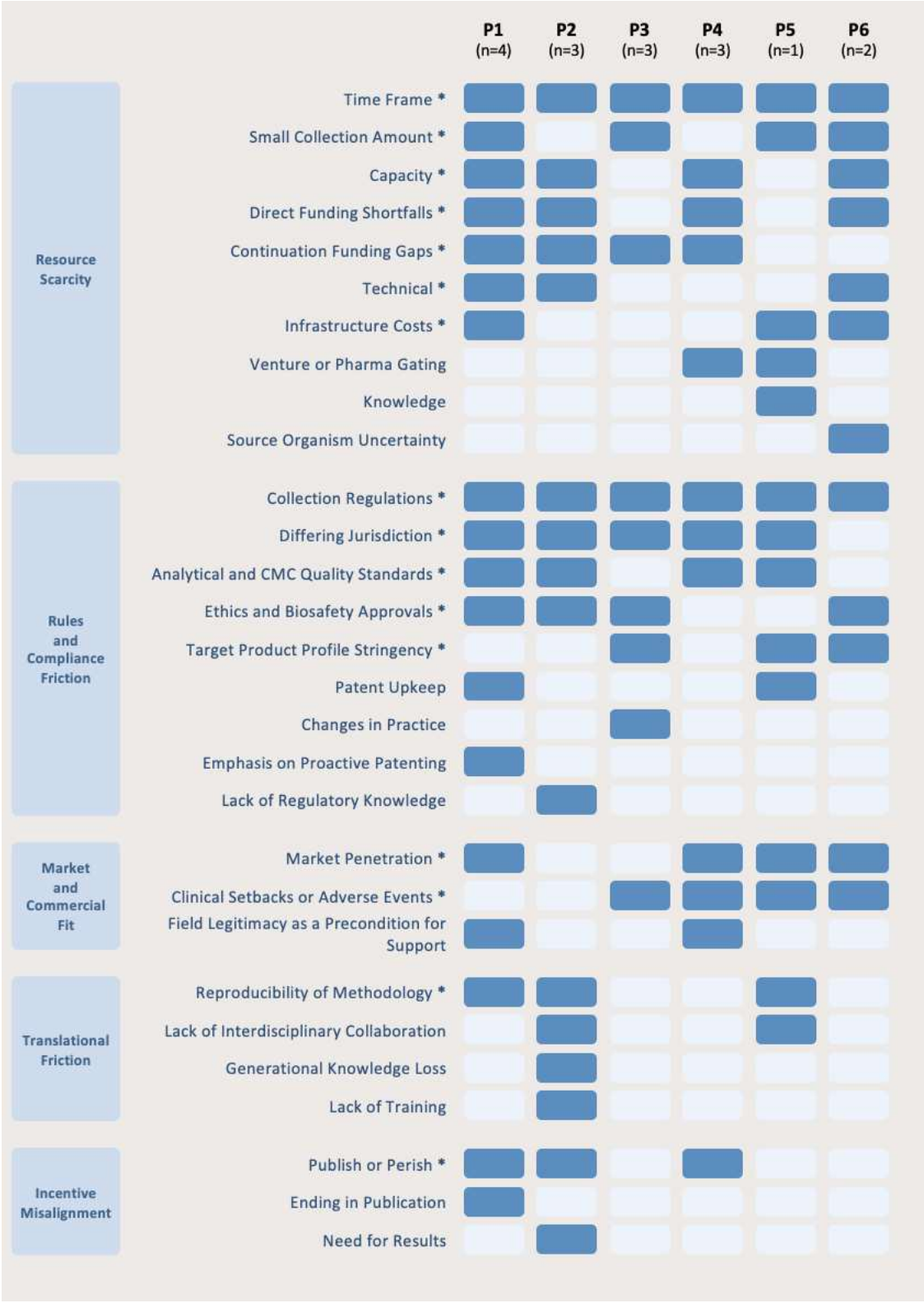


Figure 5. Thematic saturation of stakeholder transcripts

Overall, stakeholders described a variety of challenges, as well as requirements, placed upon them within the MNP field. A total of five major themes, corresponding to 177 coded references across 169 distinct spans, from a total of 461 references coded across the full content, emerged from the analysis of 16 transcripts. Based on further analysis of the thematic codes and correlating count, 29 distinct barriers were identified, eleven of which recurred in at least four of the six projects. These were subsequently grouped by overarching themes, as seen in **Figure 6**.

Not every concept/theme named in the interviews was reported as a barrier. The code *Reported as Not a Barrier* accounts for 19 references from 11 participants across all six projects. Several participants stated that a requirement was met without friction because their institution was structured to meet it. As one put it “There were no challenges and scientific issues... in my labs.” However, a constraint a participant never reached because the work stopped before that stage is not recorded/captured via the interview, and in analysis of six halted projects, that exclusion condition sets up how the finding is read.



353

354 Figure 6. **Barrier occurrence across the six projects.** Each row is a barrier code, grouped under its
355 overarching theme; a filled, darker-blue cell indicates the barrier was coded in that project and an
356 empty cell that it was not. The breadth of each code (the # of projects in which it was raised) is

shown by the number of filled cells in its row. Codes raised in 3 or more projects are shown by an *. The figure reports breadth, not frequency. Barriers are shown by whether they were raised in a project, not by how often they were mentioned, and pure reference counts are not used to shade or size any cell. Barriers raised in few projects but stressed strongly are taken up qualitatively in the text.

These barriers are organized into the five themes of the codebook (Figure 6), providing a more structured approach to understanding the challenges within the MNP pipeline. Most of these barriers are shared with natural-product drug development overall. A smaller set, centered on compound supply and sourcing, is distinctive to marine systems. The two are distinguished in the Discussion.

The organization into five themes highlights both shallow and deep leverage points, enabling prioritization and design of potential interventions that address multiple barriers, as opposed to treating the challenges in isolation. It also facilitates the prioritization and creation of targeted interventions to address each barrier, as found later in the discussion.

Outside of the scope of Fig. 6 when asked if there were any specific scientific challenges within the project, two stakeholders indicated ‘none.’

Separately, four stakeholders identified the need to create a better scheme for rewarding countries of origin. Most envisioned this as monetary benefit sharing, over potential non-monetary benefits. Comments on this topic were not specific to the project in question, but rather the generic protocol of rewarding countries of origin as it relates to the MNP field.

The following sections provide expanded insights into each barrier group, supplemented by relevant stakeholder commentary and relevant literature.

3.0 Expanded Insights on Key Barrier Groupings:

3.0.1 Resource scarcity

Resource scarcity was the most frequently reported theme, with 84 references, and it recurred across the entire sample. Three codes dominated: the small amount of compound obtainable (19 references), the time a project consumes (16), and shortfalls in laboratory capacity (16). Material scarcity is a marine-specific constraint at the start of the pipeline, as one chemist described: “the main challenge is the availability of the compound. So, you have a scarce amount, which is fine [for small-scale work]” at the early stages. It becomes more of a stressor later in the pipeline, where in vivo work needs quantities that an academic lab cannot easily supply through recollection or synthesis. Funding scarcity, taken as a group, adds a further 24 references across direct shortfalls (11), continuation gaps (5), venture or pharma gating (5) and infrastructure costs (3), and it was described as persisting across the pipeline, and worsening in the recent economy “We used to have pots of money. We could just send the collector out for recollection. But right now, that’s very scanty.” Capacity was the point at which projects were reported to stall before the in vivo stage: “the reason ours made it further in the pipeline... is they had in-vitro assays, but you have to move to the in-vivo and that was a hurdle.” The constraint of small collectable volumes is long documented for marine and other genetic resources, as demonstrated in the case of *Dolabella auricularia* and its derivatives (Gerwick and Moore 2012; Ciesielczuk and Kirk 2022).

3.0.2 Rules and compliance friction

Rules and compliance friction was the second-largest theme, with 56 references, and it recurred across most projects. Collection regulations (13 references) and differing jurisdictions (9) reflect the conservation, and access-and-benefit-sharing¹¹ considerations that marine sourcing must operate in: “some of the regulations that covered that [meant] that we didn’t want to go into an area and then just completely collect the entire population.” The largest cluster inside this theme is the set of quality requirements a compound must meet, which decomposes into analytical and chemistry, manufacturing, and controls (CMC) standards (14 references), target-product-profile stringency (9) and ethics and biosafety approvals (6), altogether 29 references. Patent-related friction sits here as well, since it is a process and compliance constraint rather than a resource one: “People from academia tend to apply for patents very quickly.” This is a problem because a patent’s protection runs for a fixed term from its filing date. Filing early, before the long preclinical and clinical work a marine natural product still needs, means much of that term elapses during development. Thus, even where patent-term extensions recover part of the lost time, little exclusivity may remain once a compound reaches the market. Academic groups rarely have dedicated support to manage this timing at the level of oversight needed.

Access and permitting delays were reported to consume a substantial share of project time, as one stakeholder described: “we started the material transfer agreement (MTA) once we got the confirmation that the project was approved... we got it approved four months after the project started.”

3.0.3 Market and commercial fit

Market and commercial fit accounts for 19 references. Difficulty reaching the market (*market penetration*, 9 references) was reported alongside *clinical setbacks and adverse events* (7 references), which halted projects late in development, and a smaller concern (*field legitimacy*, 3 references) that a project’s ability to attract funding and partners depends on how seriously the marine natural product field is taken as a source of drug candidates. This theme, as well as the aspects of resource scarcity that covered scaleup, is where the commercial gap that defines the valley of death is most directly named by participants.

3.0.4 Translational friction

Translational friction accounts for 13 references and concerns the transfer of knowledge and people rather than on material or money captured under *resource scarcity*. *Generational knowledge loss and a lack of training* (four references together) were reported as specialist expertise ageing out without replacement, and a *lack of interdisciplinary collaboration* (5 references) as the decline of the academia-to-industry handoff and collaborative efforts: “in the days when I was in small industry and large, we would look for academics and take materials and develop them with them, but not anymore.” *Reproducibility of methodology* (4 references) completes the theme. These barriers were raised by fewer participants, so they are reported as present rather than prevalent. Ten of the sixteen participants reported external collaboration by necessity, driven by their capacity to continue the work at a given stage and not having the resources available to continue the project within their lab alone. The decline of tacit, cross-disciplinary training was described directly: “[once], you were not

¹¹ ABS; rules governing permission to access genetic resources and the sharing of the resulting benefits with provider countries (Secretariat of the Convention on Biological Diversity 2011; Casolari et al. 2025).

436 that specialized that you couldn't end up learning from someone on the next bench... the days of ... a
437 multidisciplinary approach is not there."

438 3.0.5 Incentive misalignment

439 *Incentive misalignment* is the smallest theme, with 5 references, but it names a structural and/or
440 social aspect, rather than a technical constraint. *Publish-or-perish pressure* (3 references), the *need*
441 *for results* (1) and *projects ending in publication* (1) reflect academic reward structures that do not
442 align with carrying a compound toward the market. When asked directly about scientific challenges,
443 three stakeholders instead described their project as ending "only in a publication," which locates the
444 constraint in the reward structure rather than in the science. Its low count should be read as low
445 prevalence in these interviews, not as low importance.

446 3.0.6 Decision points and their consequences

447 Beyond which barriers were reported, participants described the specific decisions that stopped,
448 delayed, or narrowed the scope of their projects. The *Enacted Decision* codes hold 45 references
449 across six projects, comprising Blocked (29 references from 14/16 participants) and Enabled (16
450 references from 9). This is the best-covered analytic material in the document set, and each reference
451 records an actor, the act, and the consequence for the work. For example, one participant described a
452 synthetic route that failed to reproduce activity: "*we had collaborated with a synthetic chemist to*
453 *fully synthesize the compound. But they found that the synthetic compound... didn't show the same*
454 *activity as the natural compounds.*" The party involved in each decision was recorded as a broad
455 category (e.g., industry, regulatory, or academic) rather than as a particular organization or
456 individual. These categories are not counted or compared against each other (i.e., share of halts
457 caused by industry vs. regulators), because a single-perspective sample cannot support that
458 comparison. Each party appears only in the account of the decision it drove and that decision's
459 outcome.

460 Each *enacted decision* was coded for the party who drove it, the mechanism it enacted, and its
461 consequence for the project. This was a process-coding analysis charted as a matrix of decisions by
462 mechanism. Across the blocking decisions, the reason coded most often was economic rather than
463 scientific. In five of the blocking decisions, concentrated in two of the six projects, an industry
464 partner **declined, shelved, or deprioritized** a compound for its own portfolio reasons rather than
465 because the science had failed. A second, smaller cluster was regulatory or clinical-safety halts, in
466 which a regulator paused or stopped a trial after a toxicity signal. Technical failures against a
467 partner's target-product-profile (i.e., an unmet oral-bioavailability requirement) formed a further
468 cluster, as did frictions over access and benefit-sharing with provider countries and their institutions.

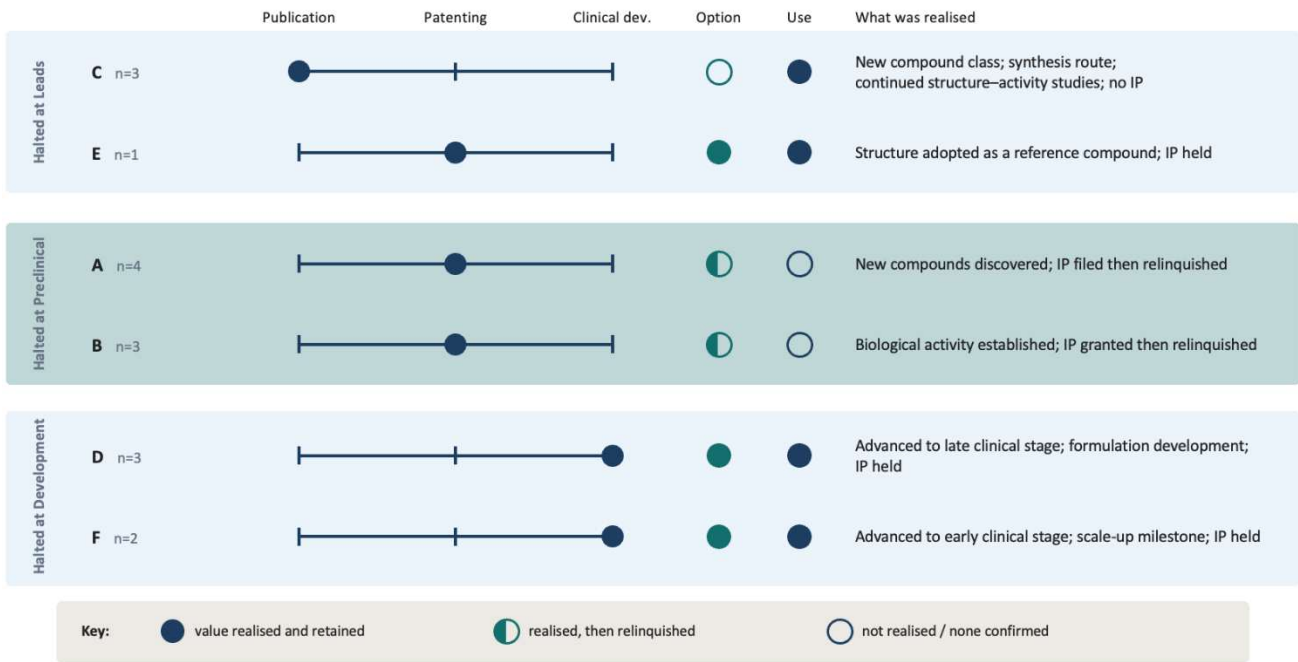
469 The enabling decisions describe how projects advanced in spite of these pressures. The recurrent
470 enabling moves were securing additional funding, forming a spin-out company to cross the
471 translational gap, adopting an enabling method or innovation (i.e., novel assay), and pivoting a
472 compound to a target or indication in which the group already held expertise.

473 Taken together, the blocking decisions suggest that project discontinuation was more often due to
474 organizational and economic reasons than to scientific problems. The enabling decisions highlight
475 the importance of resources and partnerships that were not always under the academic group's
476 control. This pattern is consistent with accounts of academic drug discovery more broadly, in which
477 promising programs stall at the handoff to development for want of resourcing and translational
478 partners rather than for want of a viable compound (Hopkins et al. 2025; Stremlau and Slusher 2025).

3.0.7 Value realized across the pipeline

Value realized was assessed using an analytical framework developed for this study. The framework draws on the concept of valorization, understood as the process of creating and capturing value (Council Recommendation (EU) 2022/2415(2022)). Concepts from total economic value were used to identify different types of value generated by the projects, while the distinction between value creation and value capture was used to consider whether this value was created or also captured (Teece 1986; Pearce and Turner 1994; Lepak et al. 2007, 2022). The three types assessed here are knowledge value¹², option value¹³, and use value¹⁴. This framework was used to assess evidence of value realization rather than to assign a monetary value to each project. Option and use value were assessed using public records rather than interview data, as indicators of how far each project progressed towards application. Knowledge value was identified in all six projects and was therefore treated as a baseline rather than a distinguishing outcome. Intrinsic value¹⁵, as described in the IPBES values typology was acknowledged but not assessed because the interviews were not designed to capture this type of value(Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) 2022). Similarly, exchange value¹⁶ was not assessed because the study did not examine market transactions or commercial outcomes and focused specifically on projects that had halted.

Figure 7 summarizes the value types realized across the six projects.



¹² The new understanding a project generates, evidenced by its published findings

¹³ The value of keeping open the possibility of future development, represented by the project's patent rights

¹⁴ Whether the compound was put to use beyond being characterized

¹⁵ The worth of an organism or compound independent of human use

¹⁶ The value realized through a market transaction

Figure 7. Value realized across the six projects, by pipeline stage at halt. Each row is one project (letter and participant count n), grouped by the stage at which work stopped (leads, then preclinical, then development). For each project the figure gives what it realised, its option value, and its use value. Option value is a three-state marker read only from the project's own patent record by the terminal disposition of its earliest right: realised and held (maintained or run to term), realised then relinquished (abandoned before term), or never realised (no filing). Use value is marked where a compound reached a use beyond characterization.

Across the six project, the earliest patent right was held or run to term in three, filed then relinquished in two, nad never filed in one. Use value, meaning the compound was actually put to use beyond being described, for example as a synthesis or supply route, a reference or tool compound, or a clinical-stage candidate, was evidenced in 4 projects. Read against *pipeline stage at halt*, these value types describe the ceiling of value realization each project reached before work stopped due to various barriers. The values are based on public record and should not be seen as either a ranking or a measure of success.

Each project's progress is listed as the stage it reached in the pharmaceutical pipeline before it halted. Against that stage, the value patterns show where value was and was not retained. The Discussion considers these patterns alongside the barriers and blocking/enabling decisions to ask what shaped each project's ability to generate value.

3.0.8 Participant-proposed interventions

Participants also highlighted the importance of strengthening translational capacity. Proposed measures included building multidisciplinary teams, preserving specialist expertise in areas such as fermentation and taxonomy, and developing incentive structures that recognize successful progression of compounds through the pipeline rather than publications alone. Several participants also identified academic spinouts as a potential mechanism for bridging the funding gap between discovery and early development. Rather than proposing entirely new structures, they emphasize strengthening the existing interfaces between academic discovery, technology transfer, regulatory support, and later-stage development.

4 Discussion

Examined together, the barriers, the decisions that halted the work, and the value each project realized can be tracked to a specific category of points in the pipeline. These points are the handoffs, where a compound passes into the next phase in the pipeline, and no single stakeholder group owns the transition. The contribution of this study is less a novel reporting of barriers than the perspective they are seen from, which is the people who participated actively in the halted projects. In (marine) drug discovery, the valley of death is usually framed as a problem of supply, scale, and chemistry. These six projects halted for differing reasons. However, more frequently the reason participants gave was not a scientific failure, but an organizational or economic decision taken outside the group. Clinical-safety events, technical shortfalls, and supply and/or scale-up challenges also ended individual projects. This pattern is visible because the projects were reconstructed at the point each one stopped. Studying projects that ended, rather than work still underway, lets the study analyze what surveys of ongoing work cannot: the barrier(s) that ended the work.

The reason named most frequently was not a failure of the science itself, but a decision taken by a stakeholder outside the academic group. In five of the blocked decisions, concentrated in two projects, an industry partner declined, shelved, or deprioritized a compound for portfolio reasons.

541 This kind of halt is distinct from the technical and regulatory barriers reported elsewhere in the
542 interviews. Two participants, when asked directly if the project encountered scientific challenges,
543 reported none. The barrier frequently sat at the handoff out of academia to the next stage of
544 development, a point the team did not control, rather than the research itself.

545 Because every interviewee was an academic describing projects they had worked on, this balance
546 should be read as how academic participants attributed the halts. Academics may be more likely to
547 locate the cause in external or organizational pressures than in their own group's science, so this is
548 not necessarily an actor-neutral audit of why each project stopped. It does, however, indicate that the
549 human dimension of the pipeline matters, and can be a resource, since complementary perspectives
550 and expertise strengthen a project.

551 Reading the same projects through the value lens set out in Section 3.0.7 sharpens the same point
552 (Figure 7). Knowledge value was realized in all six projects, since each produced published findings.
553 Therefore, it does not distinguish outcomes and is treated as the baseline of a discovery project. What
554 varied was option value, read from each project's patent record, and use value, whether a compound
555 was put to use beyond being characterized. Option value was held in three projects, relinquished in
556 two, and never created in one. Use value was evidenced in four. Both of the value types that varied
557 depend on decisions and resources beyond the bench, namely the maintenance and cost of patent
558 rights and the capacity for translational research. Read this way, the figure reframes six halted
559 projects not as six failures but as six bounded contributions:

- 560 • a new compound class
- 561 • a validated target
- 562 • an enabling synthesis route
- 563 • a reference compound
- 564 • two clinical-stage candidates

565 Each of these stopped short of the market for reasons downstream of the discovery science.

566 The barriers recur across projects and cluster into five themes, of which resource scarcity and rules
567 and compliance friction dominate. They are not isolated obstacles but are embedded in the broader
568 systemic conditions of academic lab research.

569 It is worth separating the obstacles specific to marine natural product work from those shared with
570 academic research more broadly, because that separation is a finding. Of the coded barrier references,
571 roughly 14% described constraints specific to marine work, with the remainder shared with natural-
572 product research or common to academic drug discovery overall.

573 The marine-distinctive constraints are concrete and specific(Hussain 2024). Three stand out:

- 574 • The small quantities recoverable from wild marine organisms and the difficulty of
575 resupplying them
- 576 • The uncertainty over whether an invertebrate or its microbial symbiont is the true producer of
577 a compound

578 • The difficulty of establishing marine-microbial fermentation as a reliable production route
579 (Hussain 2024).

580 • The additional regulatory burden and cost of collecting in the marine environment

581 These most affect the start of the pipeline, at supply and sourcing. The remaining and more numerous
582 barriers (i.e., funding scarcity, misaligned performance metrics, limited technology-transfer capacity,
583 and the absence of commercialization training) are shared with drug discovery more broadly and
584 dominate the handoff to development. Because the barriers that most often proved ‘fatal’ to a project
585 are shared across domains, rather than marine-specific, the greatest leverage is at the system level.
586 The marine-specific interventions, such as a shared access adviser and dependable resupply, address
587 the smaller front-end layer.

588 The imbalance is visible commercially as well. Of the 152 blockbuster drugs currently on the market,
589 only one (Adcetris®, an antibody-drug conjugate whose payload derives from the marine compound
590 dolastatin 10) is marine-derived(p. 152). Across approved drugs more broadly, natural products in
591 their unaltered form account for ~10%(Bade et al. 2010; Butler et al. 2026).

592 These barriers do more than limit how much research happens. They also steer what kind of research
593 is pursued. Participants described project objectives becoming closely aligned with predefined
594 funding priorities. This can reduce opportunities to investigate unexpected biological activities or
595 alternative translational pathways. A compound funded for an anti-cancer target may also show
596 activity against neurodegenerative disease, yet the researcher cannot pursue that lead due to funding
597 scope. In an industry setting, pursuing an activity outside the focus of funding is often harder still.
598 Thus, potentially valuable compounds may be abandoned not due to lack of scientific promise, but
599 because they fall outside the scope of the funded project.

600 Academics may view peer-reviewed publications as the successful culmination of a project, while
601 funding bodies and industry partners may expect prototypes, patents, or market-ready solutions. This
602 is an issue of misaligned key performance indicators (KPI), which can alter project trajectories and
603 funding decisions. The patent route that funders and industry partners expect can become a burden to
604 academics. Premature or defensive filings generate ongoing fees and further filings that fall hardest
605 on institutions with limited technology-transfer resources and can work against open-science
606 practice(Guns and Joossens 2016). Filing early also starts the patent-term clock, shortening the
607 commercial exclusivity that remains once a compound reaches the market. Academic groups, which
608 often lack dedicated patent-prosecution support, are poorly placed to manage this. Further,
609 researchers rarely enter a project with a commercialization strategy or the vocabulary to negotiate
610 one. Commercialization skills are unevenly distributed among academic scientists rather than a part
611 of research training. The handoff to development therefore depends on translational support the
612 group does not hold.

613 Capacity is a further constraint, and one better understood as a long-term ecosystem issue than a
614 project-level shortfall. The reported decline in specialist expertise means that maintaining disciplines
615 such as marine taxonomy and fermentation matters not only for individual projects, but for sustaining
616 the future pipeline. Many groups lacked the capacity to carry a project alone and depended on
617 external collaborators for specialized expertise and infrastructure. Therefore, interdisciplinary
618 collaboration was often essential rather than optional, and its absence caused delays(Cheng et al.
619 2020). That dependence is a vulnerability. It leaves a project reliant on the availability of specialist

620 expertise and the continuity of its collaborations. Progress comes to rest on the resilience of the
621 supporting network as much as the science.

622 Earlier work on the marine biodiscovery pipeline highlighted similar challenges such as regulatory
623 frameworks, access, species identification, and target validation(Sigwart et al. 2021). Surveys of the
624 marine bioresource sector locate its central difficulty in supply and technology. In one survey of 58
625 organizations, supply and technology was the dominant challenge for pharmaceutical and
626 nutraceutical work, ahead of funding or regulation (Collins et al. 2020). The broader literature on
627 academic drug discovery, by contrast, places the valley of death in funding, misaligned incentives
628 and thin translational capacity(Hopkins et al. 2025; Stremlau and Slusher 2025). These six halted
629 projects sit closer to the account from the academic drug discovery research. Even in a field whose
630 difficulties are usually described as chemical and logistical, the barrier most often reported at the halt
631 was organizational or economic, at a handoff the group did not control. That is visible only because
632 the projects were chosen based upon the point in the pipeline each stopped and reconstructed from
633 there. Further, the interview of experts involved in these halted projects provided a novel angle, as
634 prior surveys of organizations still operating cannot see the moment a partner shelves a compound, or
635 the value said halted project had already produced. Therefore, the contribution of this study is not
636 novel barriers, but the perspective from which the barriers are seen. Further, it contributes the finding
637 that the marine pipeline's failures are shaped less by what makes it marine than by the translation gap
638 it shares with the field of academic drug discovery.

639 The barriers are not independent problems to be solved one at a time. They share a root cause: the
640 points in the pipeline that no single actor owns, where a compound is handed from discovery to
641 development. These handoffs are where the leverage sits, because a small change there shifts the
642 whole system rather than one part of it(Cheng et al. 2020). It is also why a single intervention can
643 ease several barriers at once. Because most projects encountered barriers after the discovery phase
644 rather than in the underlying science, the interventions below focus primarily on strengthening
645 technology transfer and translational capacity, while also helping academic groups plan for the later
646 stages of development. Each intervention was developed in consultation with regulatory, industrial
647 and scientific experts and each is anchored to a codebook theme and acts on more than one barrier.

648 First, collaborative funding models should better support promising compounds as they mature.
649 Participants frequently described funding gaps between discovery and development, resulting in
650 projects that stalled despite encouraging scientific results. A planned go/no-go point within
651 collaborative projects would redirect funding and expertise toward the compounds that emerge as
652 frontrunners¹⁷ partway through rather than spreading support thin. This is a reallocation within the
653 project, not a return of funds. In a multi-partner instrument such as an EU Horizon consortium, a
654 go/no-go does not halt the grant or send money back to the funder. Rather, the budget and effort
655 committed to a compound that stalls are redirected to the frontrunner compound inside the same
656 consortium, which then becomes the collaborative project's shared focus. This addresses the practical
657 objection that partners are reluctant to stop a funded workstream midway because the remaining
658 budget is difficult to reassign. Under a pre-agreed go/no-go, that budget stays in the project and
659 follows the science. A comparable model operates in the UK Medical Research Council's complex
660 intervention framework(Skivington et al. 2021). It would force an explicit choice on whether a

¹⁷ Frontrunner selection at that point would combine a partner's assessment of developability and market fit with demonstrated bioactivity, so the choice is made against stated criteria rather than left implicit.

661 compound is headed for a patent, a publication or transfer. This would address the misalignment of
662 performance indicators directly and would require pre-agreed frontrunner criteria tested through a
663 pilot. Further, it accepts that some doctoral projects contribute to a frontrunner compound rather than
664 carrying their own to term.

665 Second, the access and benefit-sharing (ABS) rules that govern marine sourcing were among the
666 most time-consuming compliance burdens participants reported, and the requirements keep shifting.
667 A shared, funded ABS adviser held at consortium or research institute network level, would pool the
668 permitting burden across projects/institutions (i.e., through standardized agreements, IP terms that
669 can evolve as a compound moves toward commercialization, and designated project contact points).
670 This would also give researchers a living reference rather than a stale, one-time packet(Casolari et al.
671 2025).

672 Third, much of the regulatory difficulty was driven not by the complexity of the legal frameworks
673 themselves but by the practical challenge of navigating them across jurisdictions, with limited
674 institutional support and uncertainty about applicable requirements. This suggests that strengthening
675 regulatory guidance and support may matter as much as simplifying the regulations. Regulatory
676 training co-developed by legal practitioners and scientists, with simplified joint guidance and
677 toolkits, would be an intervention for this issue. This has been seen in pilots with the EU STARS
678 initiative and the PharmaSea MGR User Toolkit(Starokozhko et al. 2021). It would close the gap
679 between legal and scientific language that causes much of the reported difficulty(2026; Casolari et
680 al.).

681 Fourth, a collaborative arrangement to test compounds across a broader activity panel would let
682 activity found outside a project's funded scope lead to new work or pass to specialists instead of
683 being abandoned. A precedent exists in publicly run screening programmes. The US National Cancer
684 Institute (NCI) made its natural-product library available for screening against disease states beyond
685 cancer, so activity outside a compound's original indication could still be pursued(Thornburg et al.
686 2018). This model would rely on shared research infrastructures, as leveraged in the EUREMAP
687 Horizon Project(Tavares). Narrow, short-term funding often prevents a compound's full range of
688 activity from being explored, so a promising result outside the funded target is otherwise dropped.
689 Open compound libraries such as EU-OPENSOURCE offer one route to keep such compounds in
690 circulation when a funded target is dropped. It is best paired with intentional preservation of
691 specialist knowledge (e.g., recorded interviews, archived protocols, case studies of the field's
692 established figures). Together, these interventions make fuller use of each compound's potential, so
693 promising activity is no longer lost when it falls outside a funded scope. They also slow the
694 generational loss of expertise that this study identified as a barrier. Preserving that knowledge
695 strengthens the sustainability of the field.

696 The interventions participants themselves proposed (Section 3.0.8) point in the same direction.
697 Rather than entirely new structures, they emphasize strengthening the existing interfaces between
698 academic discovery, technology transfer, regulatory support, and later-stage development.

699 These interventions act on the structural handoffs, but they do not absolve the discovery side. The
700 size of the gaps is partly set by how discovery science is trained and practiced, so part of the remedy
701 is for academic groups to preemptively design for the handoff. They should enter a project with a
702 translational plan and the vocabulary to negotiate one, to engage technology-transfer support early
703 rather than at the point of crisis, and to build reproducibility and downstream needs into the work

704 from the start. Structural intervention at the handoffs and greater translational forethought within
705 academic groups should be complementary, not alternatives.

706 **5 Conclusion**

707 Many of the obstacles identified a decade ago persist today. This is not because they are unsolvable
708 but because they sit at handoffs that no single actor owns. Technology-transfer capacity, sustained
709 translational funding, and access machinery fall between universities, industry, and regulators, and
710 are reinforced by reward structures that credit publications over translated products. This study's
711 contribution is less a novel reporting of barriers than the perspective from which they are seen. By
712 reconstructing six halted projects from the accounts of those who worked on them, it locates where
713 value was lost vs captured. The barriers recur across projects, but the reason for each halt was more
714 often organizational or economic than scientific. Further, the value each project realized was bounded
715 less by the science than by whether transferable rights and translational capacity were in place. Most
716 of these constraints are not specific to marine work (e.g., funding, regulatory complexity, limited
717 translational capacity and commercialization support). They are the translation gap marine natural
718 products share with academic drug discovery more broadly.

719 Intervention is therefore best directed at those handoffs, while also equipping the discovery side to
720 design for them. Improving the marine natural product pipeline will require coordinated effort
721 beyond scientific discovery alone. Strengthening technology transfer, regulatory support,
722 interdisciplinary collaboration, and translational training may help bridge the gap between academic
723 research and practical application.

724 How far these interventions can be implemented, and what effect they have on translational success,
725 remains open for future research. Several participants also volunteered next steps for their own
726 compounds, from additional assays to synthetic-route or repurposing work. Because these were partly
727 prompted and fell outside the analytic frame, they are noted as directions for future work rather than
728 findings.

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735 **7 Declarations**

736 **7.0 Funding**

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739 101072475.

740 **7.1 Competing Interests**

741 The authors declare no competing interests.

742 **7.2 Ethics approval**

743 This study, involving human participants, was reviewed and approved by the University of Aberdeen
744 (Ref. 1423752, 8 November 2023).

745 **7.3 Consent to participate**

746 All participants provided informed consent to participate in this study.

747 **7.4 Consent to publish**

748 Participants consented to the use of their pseudonymized data in publications. Direct quotations are
749 reproduced only from participants who gave this consent, and all other interview data are reported in
750 aggregated, non-identifying form.

751 **7.5 Data Availability**

752 The data generated and analysed in this study are qualitative interview transcripts. Because of the
753 confidential nature of the interviews, the terms of the ethical approval granted by the University of
754 Aberdeen, and the consent given by participants, the transcripts cannot be shared, whether publicly or
755 on request, as doing so would risk identifying individual participants. The interview extracts that
756 support the findings are presented within the article. Further non-identifying material relating to the
757 analysis, such as the coding framework, may be made available by the corresponding author on
758 reasonable request.

759 **7.6 Author Contributions**

760 A.W.: Conceptualization, methodology, investigation, data curation, formal analysis, draft
761 preparation. J.M.: Methodology, reviewing & Editing. T.V.: Conceptualization, Reviewing &
762 Editing. M.J.: Conceptualization, Reviewing & Editing. I.H.: Methodology, reviewing & Editing.

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