Corpus Studies

Corpus Studies

- How often does X occur in the real world? X could be:
    - A bug
        - If it occurs often, it's worth preventing or detecting
    - A use of a feature or tool
- Is my tool applicable to real-world code?
- What is the world like?
    - e.g., what kinds of questions do people ask about Rust?

Corpus Study Techniques

- Get a corpus
    - Replicable studies require a fixed corpus
        - Snapshot of GitHub?
    - Why *this* corpus? Consider external validity.
- Write a tool or analyze manually.
- Sample?

True and False Positives and Negatives

- Context: finding needles in a haystack. (or: finding bugs in programs. or: proving that a program *lacks* a certain bug)
- Procedure: investigate each item in the haystack. Check if each item is a needle.
- True positive: This needle is a needle. 😀
- False positive: This pine cone is a needle. ☹️

Complete analyses never make this mistake

- True negative: This pine cone is *not* a needle.😀
- False negative: This needle is *not* a needle.☹️

Sound analyses never make this mistake

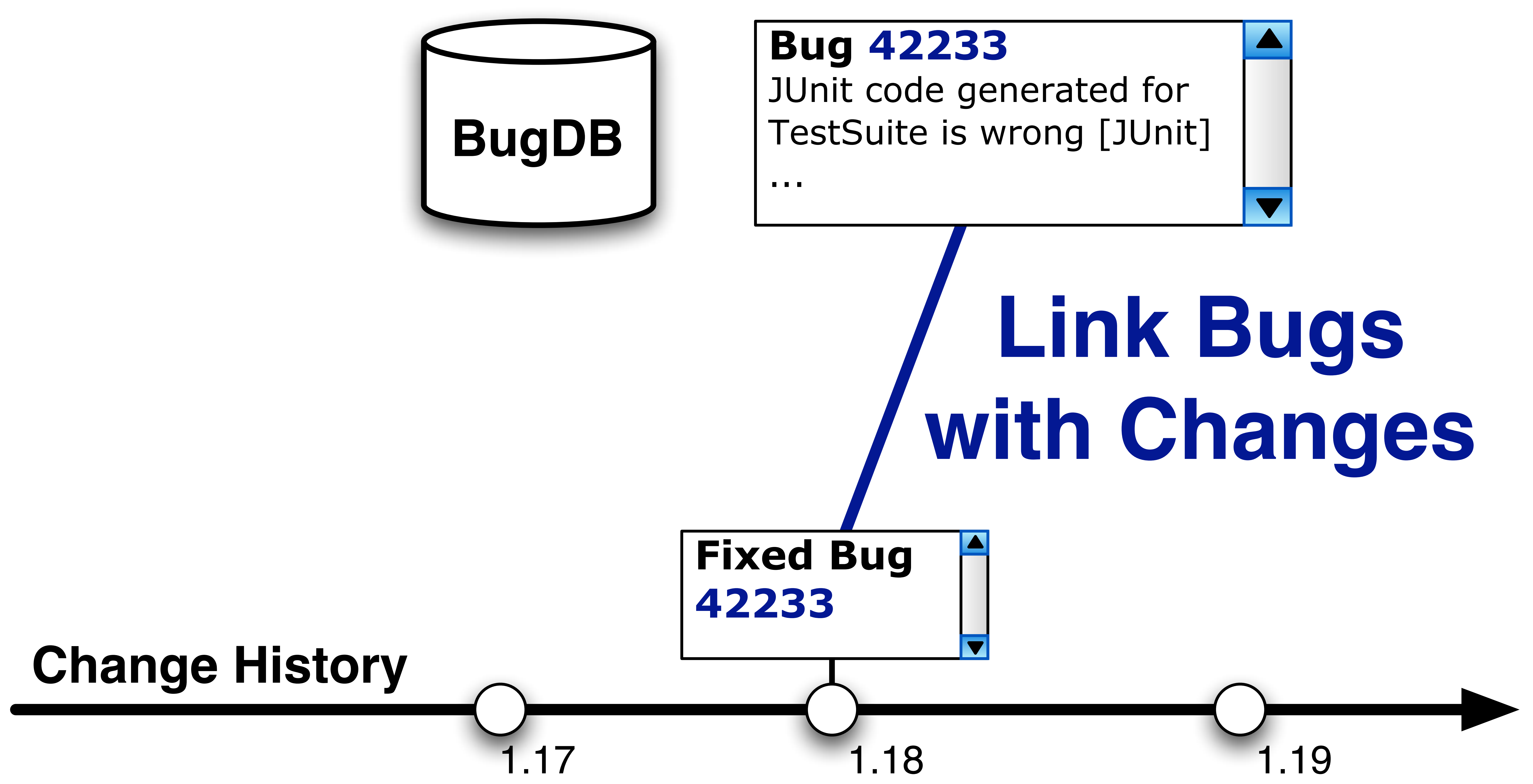
Research Questions

- RQ1: how many bugs of type X are there in this corpus? Possible answers:
  - At least n.
  - Exactly n.
  - No more than n.
- RQ2: Can my tool find bugs?
  - Yes, lots!
  - Yes, but only a small fraction of the ones that are present.
  - No, but that's because there weren't any bugs of that type.
  - No, but it's unsound, and I have no idea how many bugs there are of that type.

Analysis Techniques

- Sound analysis: find everything in category X
  - Might also find things NOT in category X
  - Mitigate with manual analysis
- Complete analysis: only find things in category X
  - But we have no idea how many we missed
- Sound and complete: nice if you can get it…
  - Rice's theorem: "all non-trivial, semantic properties of programs are undecidable."

Commits Typically Specify Which Bugs They Fix



Authors mined commit logs to find bug numbers

Corpus Study 1: When Do Changes Induce Fixes?

- Jacek Śliwerski, Thomas Zimmermann, Andreas Zeller

- RQ: When do developers insert bugs?

  - Imagine if your IDE could tell you: "your change is likely buggy!"

- Problem: how do you tell when a change inserted a bug?

- Approach: if a change's code needs to be changed AGAIN, the change induced a fix.

Fix-Inducing Changes

- "A fix-inducing change is a change that later gets undone by a fix."

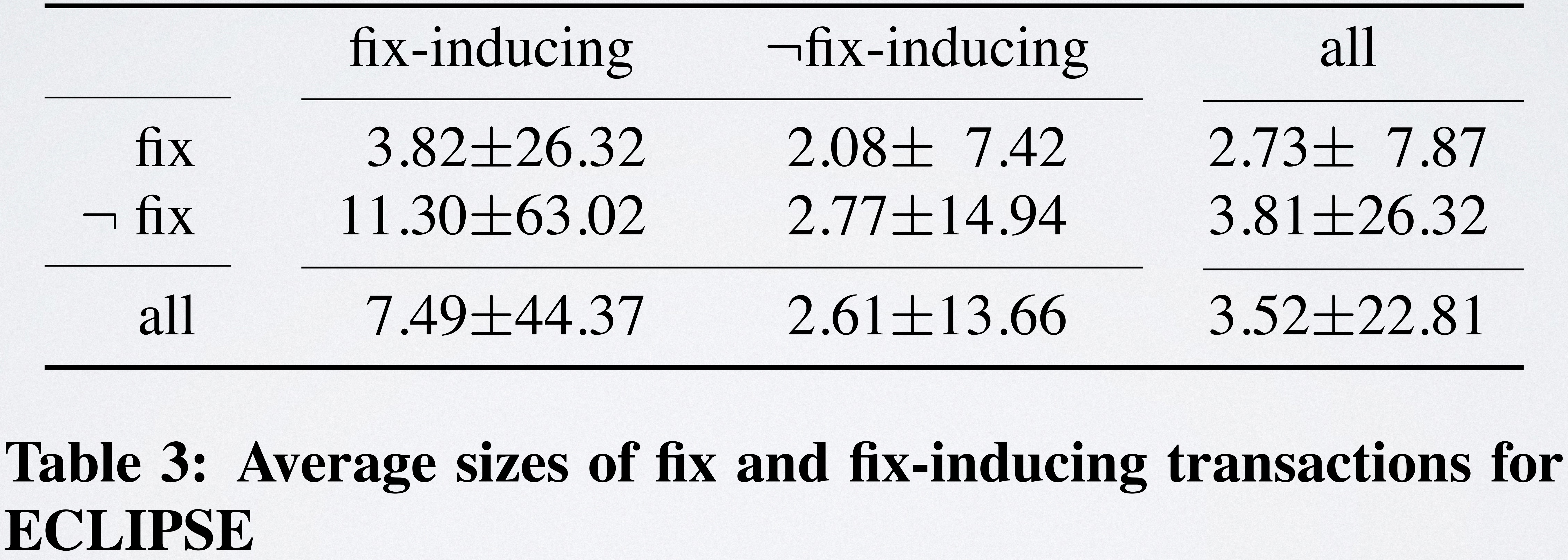
- Suppose change δ changes line 42 to fix bug B.

- Aha, revisions 675d7f and 56879a changed line 42.

- But 675d7f was committed AFTER bug B was reported, so that wasn't the cause.

- 56879a is suspect.

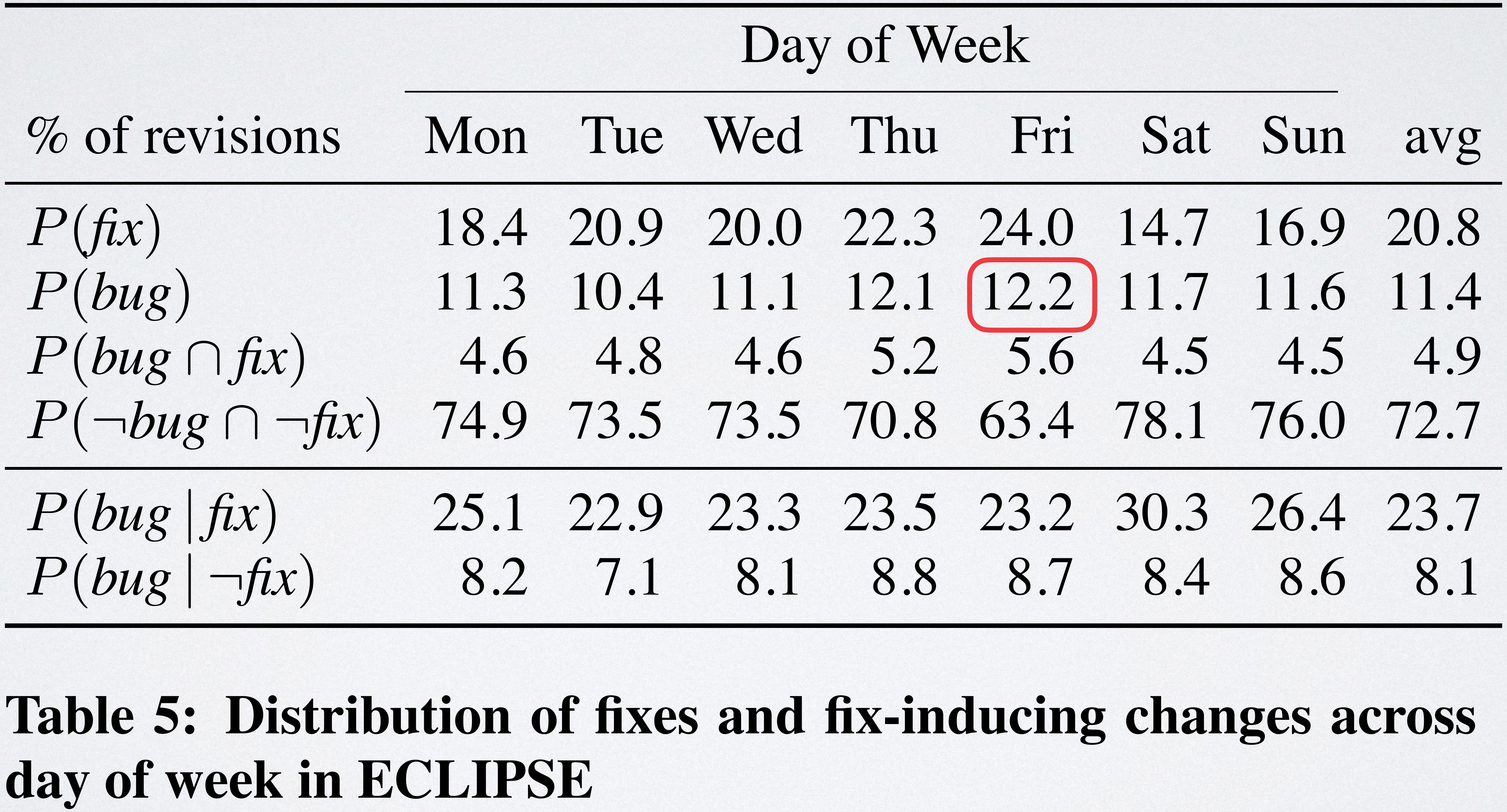
Fix-Inducing Commits Are Large



	fix-inducing	¬fix-inducing	all
fix	3.82±26.32	2.08± 7.42	2.73± 7.87
¬ fix	11.30±63.02	2.77±14.94	3.81±26.32
all	7.49±44.37	2.61±13.66	3.52±22.81

Table 3: Average sizes of fix and fix-inducing transactions for ECLIPSE

Don't Commit on Fridays



	Day of Week							
% of revisions	Mon	Tue	Wed	Thu	Fri	Sat	Sun	avg
$P(\mathit{fix})$	18.4	20.9	20.0	22.3	24.0	14.7	16.9	20.8
$P(\mathit{bug})$	11.3	10.4	11.1	12.1	12.2	11.7	11.6	11.4
$P(\mathit{bug} \cap \mathit{fix})$	4.6	4.8	4.6	5.2	5.6	4.5	4.5	4.9
$P(\neg \mathit{bug} \cap \neg \mathit{fix})$	74.9	73.5	73.5	70.8	63.4	78.1	76.0	72.7
$P(\mathit{bug} \mid \mathit{fix})$	25.1	22.9	23.3	23.5	23.2	30.3	26.4	23.7
$P(\mathit{bug} \mid \neg \mathit{fix})$	8.2	7.1	8.1	8.8	8.7	8.4	8.6	8.1

Table 5: Distribution of fixes and fix-inducing changes across day of week in ECLIPSE

Explanation?

- Maybe developers commit without as much testing or review on Fridays because they don't want to leave tasks pending over the weekend.

Another Example: Object Protocols

- Example: a File is either `Open` or `Closed`.
- On `Open` file: `close()` ok. `open()` illegal.
- On `Closed` file: `open()` ok. `close()` illegal.
- "Definition: A type defines an object protocol if the concrete state of objects of that type can be abstracted into a finite number of abstract states of which clients must be aware in order to use that type correctly, and among which object instances will dynamically transition."

Finding Protocols

```
// from java.util.concurrent.ArrayBlockingQueue.Itr
public void remove() {
  final ReentrantLock lock = ArrayBlockingQueue.this.lock;
  lock.lock();
  try {
    int i = this.lastRet;
    if (i == -1)
      throw new IllegalStateException();
    lastRet = -1;
    // ... method continues
}

// from javax.swing.undo.AbstractUndoableEdit
public void undo() throws CannotUndoException {
  if (!canUndo()) {
    throw new CannotUndoException();
  }
  hasBeenDone = false;
}

public boolean canUndo() { return alive && hasBeenDone; }
```

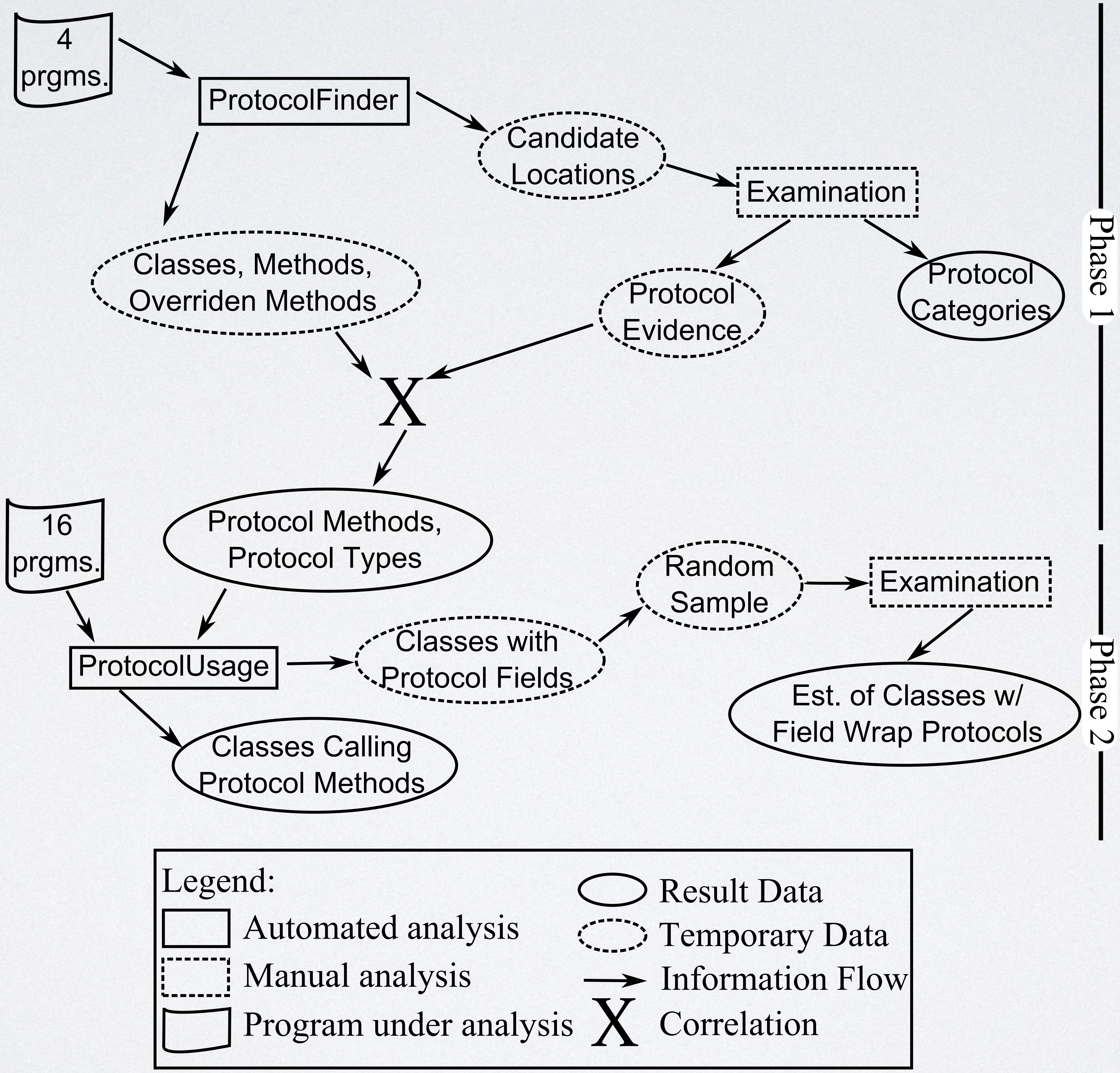
Strategy: find exceptions that are thrown conditionally, depending on field data.

Sound?
Complete?
What is an object protocol, anyway?

Method

- Phase 1: find protocols
  - Static analysis to find candidate protocols (unsound, incomplete)
  - Manual investigation of reports
- Phase 2: find how often protocols are used
  - Find calls to protocol methods

An Empirical Study of Object Protocols in the Wild



Analysis

- Dynamic analysis?
  - False negatives (missing protocols due to lack of test cases)
- Manual analysis?
  - Too slow/expensive
- Static analysis?
  - False positives

ProtocolFinder

- Sound (does it find every protocol)?
  - No (not even with respect to the paper's definition of *protocol*)
- Complete (does it ONLY find protocols)?
  - That depends on what a protocol is.

```
if (f()) {
  throw new Error();
}
```

- What about a broader definition of *protocol?*

Corpus (Phase 1)

- Four open source programs from Qualitas corpus
    - Large, popular programs; mix of libraries and applications
- 1.9 MLOC (Java)
- To what do you expect the results to generalize?
- What corpus would you have picked?

Number of Protocols

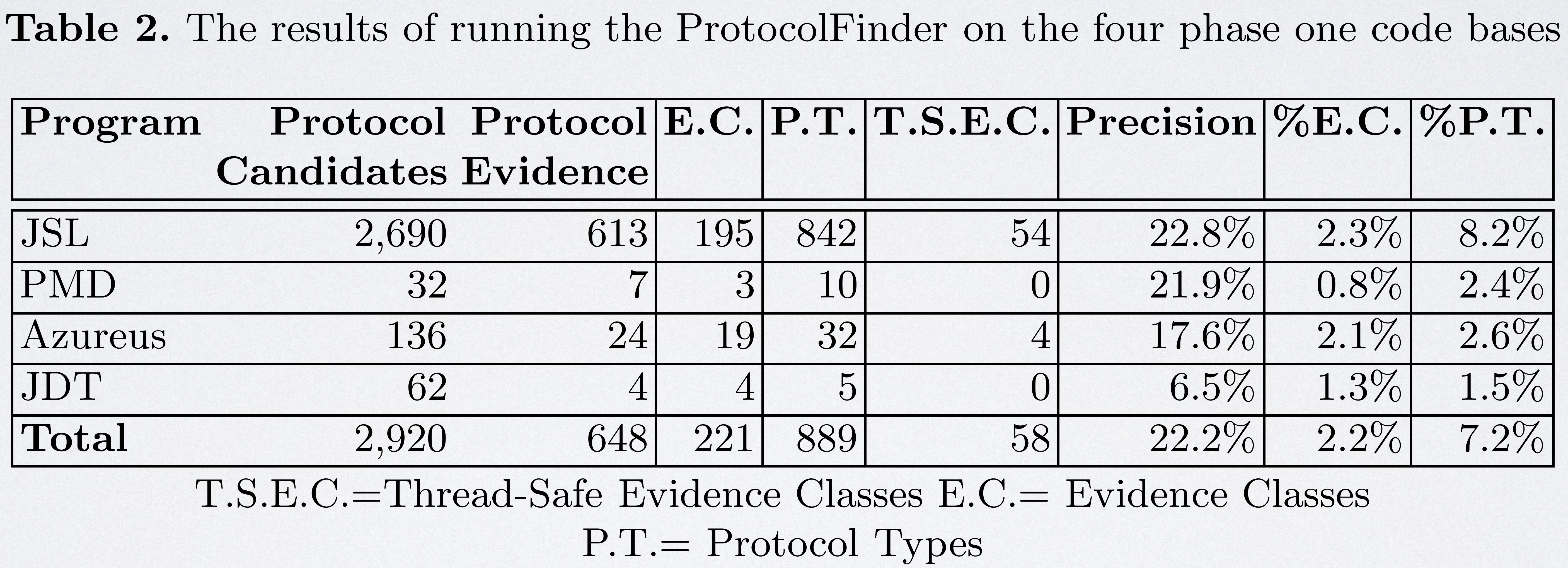


Table 2. The results of running the ProtocolFinder on the four phase one code bases

Program	**Protocol Candidates**	**Protocol Evidence**	**E.C.**	**P.T.**	**T.S.E.C.**	**Precision**	**%E.C.**	**%P.T.**
JSL	2,690	613	195	842	54	22.8%	2.3%	8.2%
PMD	32	7	3	10	0	21.9%	0.8%	2.4%
Azureus	136	24	19	32	4	17.6%	2.1%	2.6%
JDT	62	4	4	5	0	6.5%	1.3%	1.5%
Total	2,920	648	221	889	58	22.2%	2.2%	7.2%

T.S.E.C.=Thread-Safe Evidence Classes E.C.= Evidence Classes
P.T.= Protocol Types

Types of Protocols

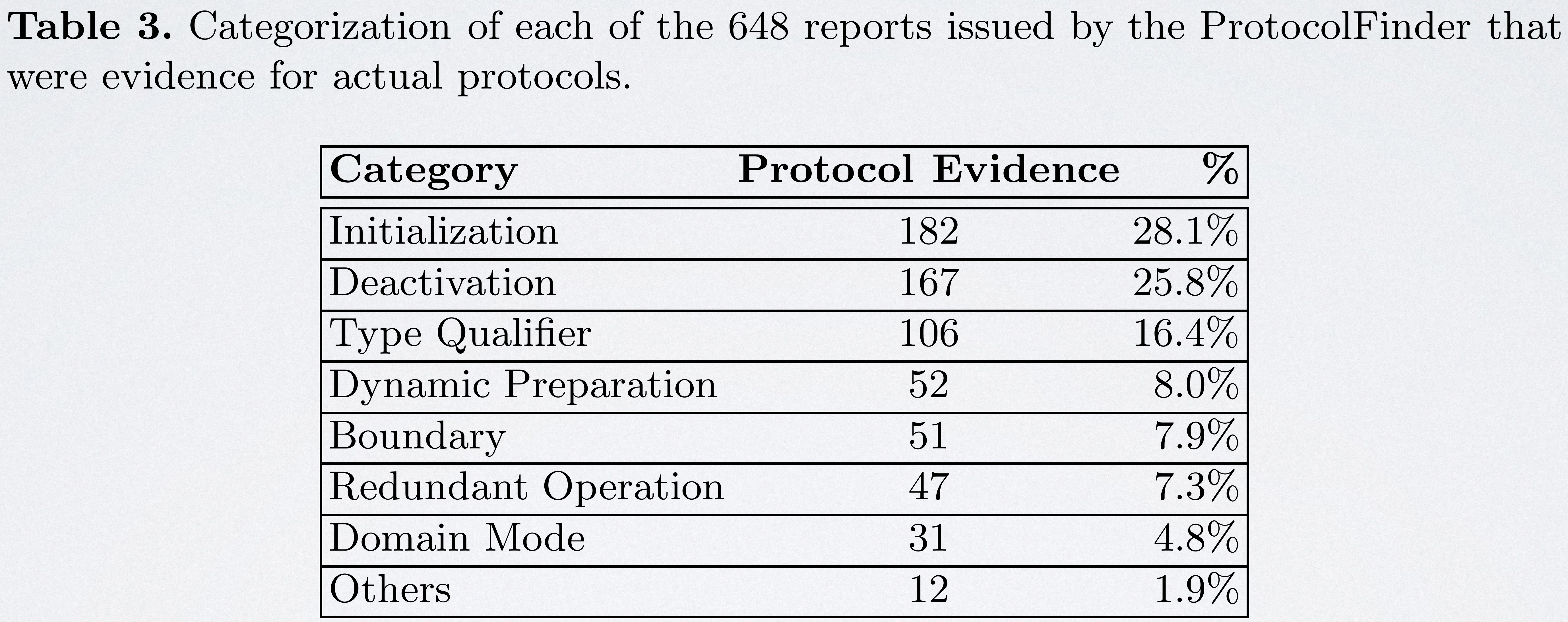


Table 3. Categorization of each of the 648 reports issued by the ProtocolFinder that were evidence for actual protocols.

Category	**Protocol Evidence**	**%**
Initialization	182	28.1%
Deactivation	167	25.8%
Type Qualifier	106	16.4%
Dynamic Preparation	52	8.0%
Boundary	51	7.9%
Redundant Operation	47	7.3%
Domain Mode	31	4.8%
Others	12	1.9%

Phase 2: Protocol Usage

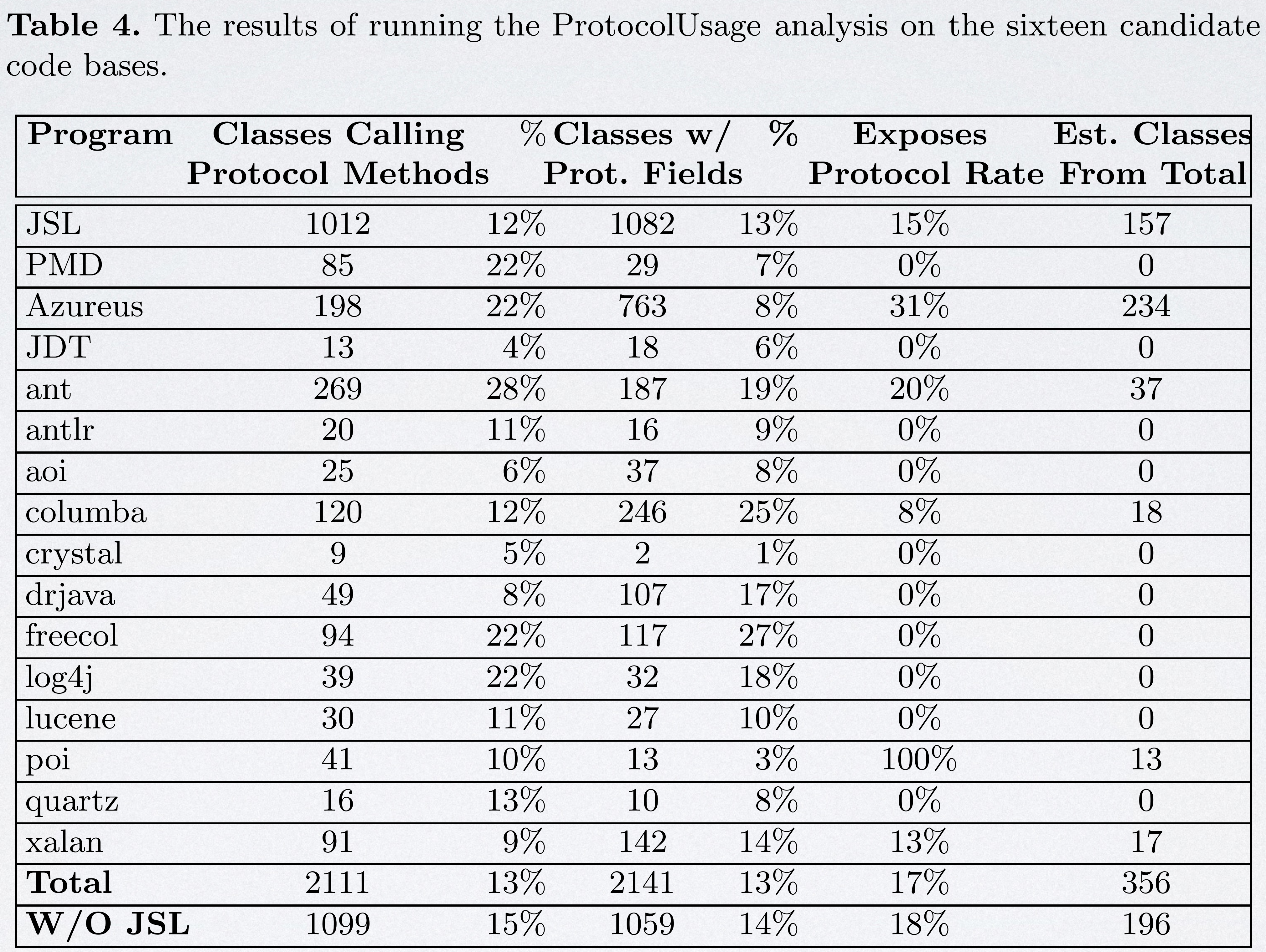


Table 4. The results of running the ProtocolUsage analysis on the sixteen candidate code bases.

Program	**Classes Calling Protocol Methods**	**%**	**Classes w/ Prot. Fields**	**%**	**Exposes Protocol Rate**	**Est. Classes From Total**
JSL	1012	12%	1082	13%	15%	157
PMD	85	22%	29	7%	0%	0
Azureus	198	22%	763	8%	31%	234
JDT	13	4%	18	6%	0%	0
ant	269	28%	187	19%	20%	37
antlr	20	11%	16	9%	0%	0
aoi	25	6%	37	8%	0%	0
columba	120	12%	246	25%	8%	18
crystal	9	5%	2	1%	0%	0
drjava	49	8%	107	17%	0%	0
freecol	94	22%	117	27%	0%	0
log4j	39	22%	32	18%	0%	0
lucene	30	11%	27	10%	0%	0
poi	41	10%	13	3%	100%	13
quartz	16	13%	10	8%	0%	0
xalan	91	9%	142	14%	13%	17
Total	2111	13%	2141	13%	17%	356
W/O JSL	1099	15%	1059	14%	18%	196

Implications on Language Design

- Do you wish you had typestate?
- Do these results mean we should?