

Isok -- A query centered monitoring tool for PostgreSQL

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1 Introduction to Isok

Isok is a **PostgreSQL extension** for monitoring anything that can be reported with an SQL query. Its expected usage targets data integrity maintenance and data cleanup. One expected use-case is addressing those corner cases where business logic is "fuzzy" and database content is monitored for unusual but not prohibited content. There is also a potential use-case for monitoring for errors in data, although it can be best to use constraints and triggers for this purpose because these prevent erroneous data from getting into the database in the first place.

Isok lets you run SQL to produce reports alerting you of suspicious or erroneous conditions, with features to suppress previously reported alerts. It is useful when periodically probing for unusual but allowed activity, such as the purchase of more than 1,000 shoes by one person. Approved excessive shoe purchases can be individually flagged so they do not appear in future reports. To avoid being overwhelmed by numerous legitimate alerts and to allow time to resolve issues, specific rows in the reports can be deferred so they do not reappear before a designated date.

Unlike triggers and constraints, Isok does nothing until executed. This is done by selecting from a function, which runs some or all of the saved queries to check the state of the database and report the results. Report content is archived and can be queried.

Reported issues are classified as either errors or warnings. Errors are always reported when Isok is run. After execution, the warnings reported by the user-supplied queries may be manually sorted by the Isok user into one of the following categories: unclassified (the default), labeled "resolved", or deferred until a later date. When Isok is run, unclassified warnings are reported, "resolved" warnings are not reported, and deferred warnings are not reported until the current date reaches the deferral date.

PostgreSQL supports a high degree of introspection. Isok can therefore monitor PostgreSQL itself, both the database engine's operational metrics and database schema design. In the former case system performance or usage might be monitored. In the latter, monitoring might look for things like violations of column naming conventions. However, while there may be legitimate uses of Isok for these sorts of purposes, other tools may be a better fit.

Regardless of how Isok is used, we believe some monitoring and some error checking is better than no monitoring and no error checking. Isok makes monitoring and error checking easy. If introducing triggers into your processing or running a complete performance monitoring solution is just not feasible, Isok provides a simple way to move the ball at least a little bit closer to the goal.

2 Installation

There are two steps to installation, first, getting and preparing the code and, when installing as an **extension**, installing into the OS, and, second, loading into one or more databases.

Note

Installing Isok into the OS, which is necessary when installing as an **extension**, typically requires elevated OS-level privileges, such as **root** privileges. The examples given do not include the assumption of elevated privileges, or show the use of any particulars, such as the **sudo** command, needed to assume such privileges.

Similarly, the examples do not include the **connection parameters** (usernames, passwords, hosts, database names, etc.) which may be needed to connect to a database.

Regardless of how Isok is installed, we recommend you install it in a dedicated **schema**. Dedicating a schema to Isok has a number of benefits, not the least of which is simplified access control to mitigate **security concerns**.¹ When a schema is created, only the owner can access its content. This is sufficient protection, assuming care is taken using the **ISOK_QUERIES.Role** and **ISOK_QUERIES.Search_Path** columns. (Or, if these **features are disabled**.)

2.1 Requirements

Isok installs on **PostgreSQL** version 10 or later, although **PostgreSQL** versions no longer supported by The PostgreSQL Global Development Group may not get support.

2.2 Quick-Start

The simplest way to get and prepare Isok is to use **pgxnclient**. Your operating system probably has a **pgxnclient** package available.

The **pgxnclient** package must be installed on the machine running your **PostgreSQL server**. If you're running a managed instance of **PostgreSQL**, in the cloud or otherwise, and don't have access to the machine running the **PostgreSQL** cluster, you'll need to use another installation method.

After installing **pgxnclient**, the command:

```
pgxn install pg_isok
```

makes the Isok extension available to **PostgreSQL**. Then, executing SQL like:

```
CREATE SCHEMA isok;  
CREATE EXTENSION pg_isok SCHEMA isok;
```

loads Isok into your database and makes it available for use.

¹The downside to installing in a schema is that when writing SQL you must either set your **search_path** or qualify names, by prepending the object name with the schema name and a period. For example, without setting a search path, if you installed into a schema named **isok**, instead of **SELECT * FROM run_isok_queries()**, you would have to write **SELECT * FROM isok.run_isok_queries()**.

2.3 Preparing, While Logged-In to Un*x

Installing as an **extension** requires that the installation be done while logged into the **PostgreSQL server's** machine. Or, at minimum, while the **current working directory** is within the server's **filesystem**.

Installing from SQL, as is necessary when the **PostgreSQL's** server's filesystem is unavailable, must be done from a machine able to work as a **PostgreSQL client**.

The recommended download is the **Isok zip file** "distribution" from **PGXN.org**. It is "pre-built", and so does not require installation of any build tooling. If you have this, after unzipping, you can skip over the next sections, which cover **disabling features**, and **cloud installation**, and skip straight to Section 2.3.3.

It is also possible to clone the **Isok git repository**, but be forewarned. Working from the git repository requires the installation of **considerable tooling**.

Note

Any rebuild of Isok requires the installation of the **m4** macro pre-processor.^a Your operating system almost surely makes available an **m4** package.

Only the "pre-built" PGXN distribution can be installed without the use of **m4**.

^aPossibly, the **GNU m4 implementation** is required. This is what **PostgreSQL** requires, and alternatives have not been tested.

2.3.1 Re-Building to Disable Features

If desired, some potentially dangerous features of Isok can be disabled at build time.

These are the **make** variables that control the build options:

DISABLE_ROLE Disable the ability to **SET ROLE** from **ISOK_QUERIES**.

DISABLE_SEARCH_PATH Disable the ability to **SET** the **search_path**.

To use these variables, set them to any value when running **make**. For example, to disable all optional features run:

```
make DISABLE_ROLE=y DISABLE_SEARCH_PATH=y
```

The build configuration is documented in the **doc/pg_isok--\${VERSION}.config** file, and installed with the rest of the documentation.

2.3.2 Building for and Installing in The Cloud (Installing With SQL)

If you are running in the cloud, or some other managed instance where you do not have permissions on the host running PostgreSQL, you will not be able to install Isok as an extension. In these cases you can still install Isok, but you must first build its SQL and then manually execute it.

Of course, this installation method can always be used, as there is always a way to execute SQL.

To build a “cloud version” of Isok, suitable for installation by SQL execution, you would type something like:

```
make TARGET_SCHEMA=isok pg_isok_cloud--$(cat VERSION).sql
```

The resulting sql file is in the **sql/** directory.

To customize the build, any of the **above** variables may also be set. The **TARGET_SCHEMA** variable must be set; the objects produced by the generated SQL must be located within a designated **schema**. It is highly recommended that the **TARGET_SCHEMA** be lower-case and otherwise be a PostgreSQL name which does not require quoting.

To install, first create the **schema** and then execute the sql. The command line interaction, if you use the **psql** command line client interface, would look something like:

```
$ psql
psql (15.13 (Debian 15.13-0+deb12u1))
Type "help" for help.

me=> CREATE SCHEMA isok;    -- The TARGET_SCHEMA used to build the sql
CREATE SCHEMA
me=> \i sql/pg_isok_cloud--1.0.0.sql
<lots of output redacted>
me=> \q
$
```

You must re-build different SQL, with a different **TARGET_SCHEMA**, in order to install into a different schema.

2.3.3 Installing in the PostgreSQL Server's OS

With appropriate OS-level permissions, run:

```
make install
```

With this step complete, you are ready to **install the Isok extension** into any schema of any database in the **cluster**.

2.3.4 Running Regression Tests

Once an extension has been **installed in the OS**, regression tests can be run to test whether Isok is operating correctly. Running the regression tests when Isok is installed **by SQL execution** is unsupported.

The same **build variables** must be set when running the regression tests as when the system was built. (The PGXN distribution sets no variables, the default.) Should you set a different collection of variables than when building, some tests will fail and others may fail to run at all.

The following example runs the default set of regression tests:

```
make installcheck
```

2.4 Loading Into PostgreSQL

The **CREATE EXTENSION** command is used to install Isok, as in the following example:

```
CREATE SCHEMA isok;  
CREATE EXTENSION pg_isok SCHEMA isok;
```

2.5 Uninstalling

2.5.1 Uninstalling From the OS

Uninstalling from the OS does the opposite of installing. It removes the extension from the **PostgreSQL** server's filesystem.

To uninstall with `pgxnclient`, run:

```
pgxn uninstall pg_isok
```

To uninstall using **make**, run:

```
make uninstall
```

Because Isok is pure SQL, uninstalling it from the OS does not remove any functionality from existing instances installed with **CREATE EXTENSION**. Uninstalling does, however, remove the ability to use the **CREATE EXTENSION** to install Isok in a schema.

2.5.2 Uninstalling From PostgreSQL

Running:

```
DROP EXTENSION pg_isok;
```

removes the extension from all schemas in all PostgreSQL clusters.

To remove an installation of Isok from an individual schema, drop the schema with **DROP SCHEMA schemaname CASCADE;**

3 An Overview of the Isok Tables

This section provides an overview of Isok's tables.

Table	One row for each...
ISOK_QUERIES	query used to discover data integrity problems
ISOK_RESULTS	data integrity problem discovered by Isok

Table 1: The Isok Tables

Table	Id Column	Related Column(s)	One entry for every possible choice of...
IQ_TYPES	IQType	ISOK_QUERIES.Type	kind of problem with data integrity
IR_TYPES	IRType	ISOK_RESULTS.Category	remark which might apply to more than one instance of questionable database integrity

Table 2: The Isok Support Tables

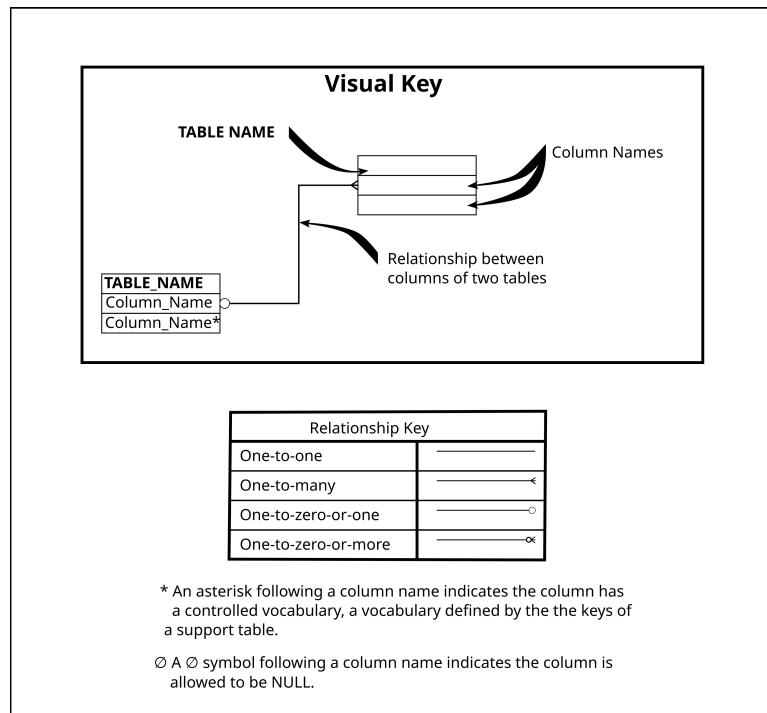


Figure 1: Key To Entity Relationship Diagrams

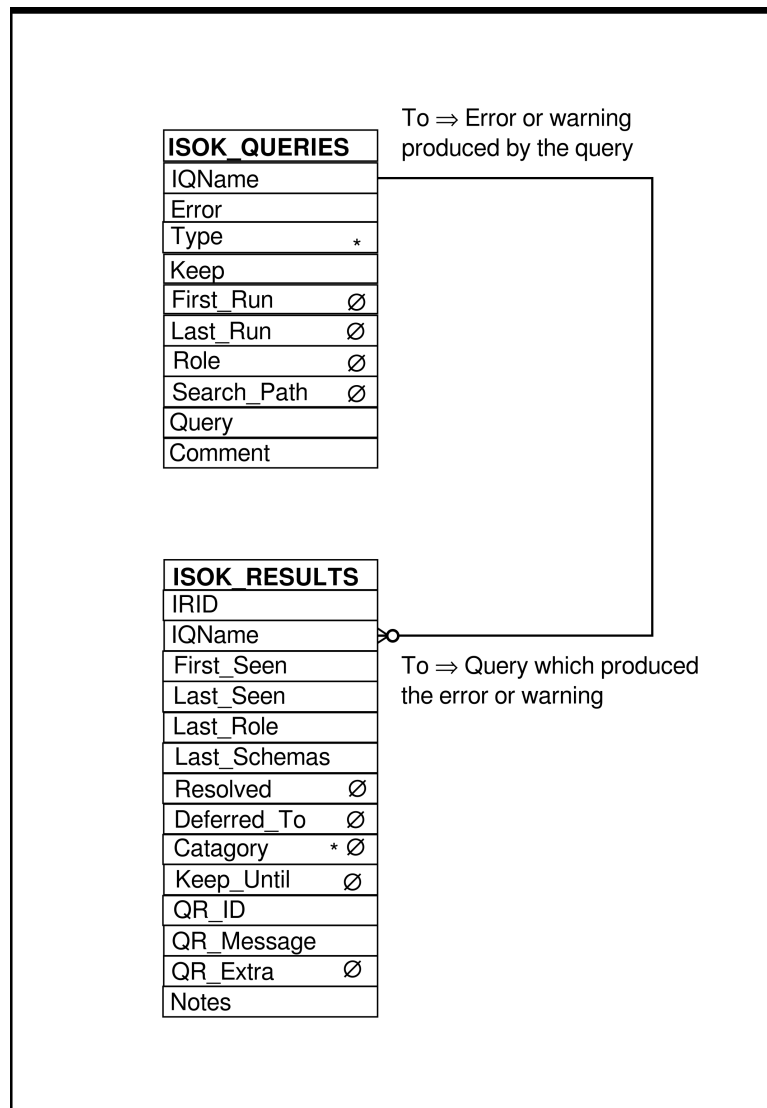


Figure 2: Isok Entity Relationship Diagram

4 The Isok Main Tables

In the table descriptions below, each table has it's own section, with sub-sections for the table's columns.

All timestamps (date plus time values) have a one second precision. Fractions of a second are not recorded.

All timestamps track the time zone.

4.1 ISOK_QUERIES

The ISOK_QUERIES table contains one row for every query used to search for database integrity issues.

The **Last_Run** value cannot be before the **First_Run** value.

Tip

Use PostgreSQL's **dollar quoting** when inserting queries into ISOK_QUERIES using **INSERT** statements. This avoids problems that would otherwise arise involving the use of quote characters inside quoted strings.

Example 4.1 Inserting a query into ISOK_QUERIES using dollar quoting

```
-- Report a warning when there's a birth date before 1950
INSERT INTO isok_queries (iqname, error, type, keep, query, ←
    comment)
VALUES ('mycheck', false, 'bdate', false
    , $$SELECT 'Bad birth date: ' || mytable.id || ', ' || ←
        mytable.birthdate
        AS id
    , 'Id ('
        || mytable.id
        || ') has a birthdate ('
        || mytable.birthdate
        || ') before 1950'
        AS msg
    FROM mytable
    WHERE mytable.birthdate < '1950-01-01'$$
    , $$Report a warning when there's a birthdate before 1950 ←
        $$
    );
```

4.1.1 IQName (Isok Query Name)

A TEXT value. A unique name for the query. The IQName value cannot be changed. This column may not be empty; it must contain characters, and it must contain at least one non-whitespace character. This column may not be NULL. This column may not contain whitespace characters. This column must be unique when compared in a case-insensitive fashion.

4.1.2 Error

A BOOLEAN value. TRUE when the query finds conditions that are errors, FALSE when the query finds conditions that are warnings. See [ISOK_RESULTS](#) (and the Section 1) for [more](#) on warnings and errors. This column may not be NULL.

4.1.3 Type

A TEXT value. Code classifying the query. The legal values for this column are defined by the [IQ_TYPES](#) support table.

This column may not be NULL.

4.1.4 First_Run

A [timestamp](#). Date and time the query was first run by Isok. The value of this column is NULL if the query has never been run.

4.1.5 Last_Run

A [timestamp](#). Date and time the query was most recently run by Isok. The value of this column is NULL if the query has never been run.

4.1.6 Keep (Keep old results)

A BOOLEAN value. This column controls the value placed in the [ISOK_RESULTS.Keep_Until](#) column when [run_isok_queries\(\)](#) inserts new rows in [ISOK_RESULTS](#).

When this column is TRUE, each row returned by the query is stored in [ISOK_RESULTS](#) with a [Keep_Until](#) value of [infinity](#). This prevents [run_isok_queries\(\)](#) from deleting the query result row when run, when the query no longer returns the result row.

When this column is FALSE, the [ISOK_RESULTS.Keep_Until](#) value of any new rows that [run_isok_queries\(\)](#) inserts is NULL.

This column may not be NULL.

4.1.7 Role

A **PostgreSQL** name value. The **PostgreSQL** role to use to run the **query**.

Because different roles have differing access to database content, it can be useful to run queries with different roles in effect.

**Caution**

Setting the role may have **security implications**.

This column is not validated against existing roles.

Note that the `name` data type casts (transparently) to `TEXT`.

When this column is `NULL`, the effective role is not changed.

4.1.8 Search_Path

A `TEXT` value. The **PostgreSQL** schema **search_path** to have in effect when the **query** is run.

The syntax of the search path is that used by **SET search_path ...** and returned by **SHOW search_path;**

Because queries may not always contain schema names to qualify database objects, a single query can return different results depending on the **search_path** in effect. So it can be useful to run different queries when different schema search paths are in effect.

**Caution**

Setting the `search_path` may have **security implications**.

Care must be taken when setting the search path because the search path can be set to anything, regardless of which schemas exist or are available to the user. It is quite easy to set a search path that searches no schemas. **PostgreSQL** will not produce any warnings or errors should you do so.

When this column is `NULL`, the schema search path is not changed.

4.1.9 Query

A `TEXT` value. A query which checks for database integrity violations. The query need not end in a semi-colon. The query must return 3 columns. Although these columns are referred to by name below, the names the query gives to the columns does not matter.

4.1.9.1 The first returned column, the ID column

The first column is used as an id. It must contain a unique value. (Unique per results returned by the given query). The value must also be constant; repeated runs of the query which find the same problem must return a consistent value.

**Caution**

The system cannot enforce the requirement that the first column be consistent over repeated runs of the query. If the query does not satisfy this requirement Isok will generate duplicates of previously reported problems.

The value of the first column may not be `NULL` or the empty string.

Guidelines for the value of the first column are that it should be human readable and relatively short. It should probably contain id values in order to ensure uniqueness, but only those that will not change over time.

The value of this first column may need to be typed in or otherwise referenced by a person in order to make notes regarding the problem or to change the problem's status.

4.1.9.2 The second returned column, the Msg column

The second column contains a message describing the discovered database integrity problem. It should contain a complete description of the problem and may be as verbose as necessary.

The value of the second column may not be `NULL` or the empty string.

4.1.9.3 The third returned column, the Extra JSON column

The third column contains JSON data. The purpose of this column is to hold additional data on the reported condition that may need to be tracked, or queried. PostgreSQL is able to efficiently query `JSONB` data, which is how this column is stored.

Warning

At the time of this writing, in practice, returning a third column is optional. But this behavior should not be relied upon.

Best practice is to return a `NULL` value for the third column when you do not wish to store any JSON with the query result.

When only 2 columns are returned, the effect is the same as returning a `NULL` value in the third column.



The third column is optional, in practice, because a portion of the PostgreSQL PL/pgSQL language is unspecified.^a Isok cannot feasibly use the text of the Query column to determine how many columns the query returns. So it cannot prevent the query from being written to return only two columns. And, when this is the case, the present PL/pgSQL implementation allows the Query to return two columns instead of three.

^aThe unspecified PL/pgSQL behavior being, that the *target* in a PL/pgSQL statement of the form “**FOR** *target* **IN EXECUTE** *text_expression* [**USING** *expression* [, ...]] **LOOP**” is allowed to contain more variables than the *test_expression* returns columns, in which case the extra variables are assigned the `NULL` value. Because this behavior is undocumented, it is subject to change. Should this behavior change, returning a third column will be required, not optional.

Return a `NULL` value in the third column when there is no JSON data.

4.1.10 Comment

A `TEXT` value. A comment on the query. This may be as verbose as necessary. This column may not be `NULL`. This column may be empty; it need not contain characters, but it may not contain only whitespace characters..

4.2 ISOK_RESULTS (Isok query Results)

The `ISOK_RESULTS` table contains one row for every database integrity problem discovered by the queries in `ISOK_QUERIES`. That is to say, one row for every row returned by executed queries. The table’s purpose is twofold. It provides an efficient way to list data integrity problems, without having to execute the potentially complex queries which discover the problems. But it’s main purpose is to allow warnings, i.e. those problems discovered by the queries saved in `ISOK_QUERIES` rows having a `FALSE Error` value, to be resolved -- permanently marked as acceptable conditions. Resolved warnings can be safely ignored thereafter, and since Isok automatically ignores resolved warnings those responsible for maintaining database integrity need not repeatedly concern themselves with resolved conditions.

To resolve a warning place a timestamp in the `Resolved` column.

Data integrity errors can not be resolved, the erroneous data condition must be fixed -- `ISOK_RESULTS` rows must have a `NULL Resolved` value when the row has a `IQName` related to an `ISOK_QUERIES` row having a `TRUE Error` value.

The **Last_Seen** value, the **Resolved** value, and the **Deferred_To** value cannot be before the **First_Seen** value.

A resolved warning cannot be deferred -- either **Resolved** or **Deferred_To**, or both, must be NULL.²

The query result id generated by the stored query must be unique per query -- the combination of ISOK_RESULTS.**IQName** and ISOK_RESULTS.**QR_ID** must be unique.

4.2.1 IRID (Integrity Results Identifier)

An **BIGINT** value This column uniquely identifies the row containing the result of a database integrity query. The IRID value cannot be changed and is automatically generated with a **PostgreSQL sequence**.

4.2.2 IQName (Integrity Query Name)

A **TEXT** value. The **ISOK_QUERIES.IQName** value identifying the query which produced the result.

4.2.3 First_Seen

A **timestamp** value. Date and time the query result was first produced by Isok. This column may not be NULL.

4.2.4 Last_Seen

A **timestamp** value. Date and time the query result was most recently produced by Isok. This column may not be NULL.

4.2.5 Last_Role

A **PostgreSQL** name value. The role (user) which was the **current role** when the query was last executed. Note that the **name** data type casts (transparently) to **TEXT**.

This column is not validated against existing roles.

This column may not be NULL.

²To remove an **ISOK_RESULTS.Deferred_To** value and add a **ISOK_RESULTS.Resolved** value without raising an error either update both values in the same **UPDATE** statement or first set the **Deferred_To** value to NULL and then the **Resolved** value to something non-NULL.

4.2.6 Last_Schemas

An array of [PostgreSQL](#) name values. All schemas that were, implicitly or not, in the [search_path](#), and also available to the [Last_Role](#), when the result was returned. For more information, see the documentation of the [current_schemas\(\)](#) function.

Note that the name data type casts (transparently) to TEXT. This column may not be NULL.

4.2.7 Resolved (Date and Time Resolved)

A [timestamp](#) value. Date and time the query result was resolved; that is, marked not a concern. The Isok system does not display resolved results, although of course the ISOK_RESULTS table can always be manually queried.

The value of this column may be NULL. This occurs both when the query result is a data integrity error and when it is a data integrity warning that has not yet been resolved.

4.2.8 Deferred_To

A [timestamp](#) value. Isok suppresses display of the result when the current time is before this time. Use of this column allows resolution of data integrity problems to be deferred, and hence not clutter up the output of Isok with noise that might hide other problems.

When this column is NULL Isok displays the query result.

4.2.9 Category

A TEXT value. Code classifying the query result. The legal values for this column are defined by the [IR_TYPES](#) support table.

This column may be NULL when the query result is unclassified.

4.2.10 Keep_Until

A [timestamp](#) value. This column controls whether or not [run_isok_queries\(\)](#) deletes the row when the [ISOK_QUERIES.Query](#) is re-run and the query does not return the row's [QR_ID](#).

A query result that the query no longer returns is kept until the given time is reached, when the value of this column is not NULL. When the value of this column is NULL, a query result row that is no longer returned is always deleted. For further detail see the the section called “[Deletion of Old Results](#)” section of the [run_isok_queries\(\)](#) documentation.

Tip

Using the special `TIMESTAMP` value of [infinity](#) entirely prevents deletion.

4.2.11 QR_ID (Query Result Identifier)

A TEXT value. This is a unique, unique per query that is, identifier for the query result. It is the **first column** produced by the related **ISOK_QUERIES.Query**.

This column may not be NULL.

4.2.12 QR_Message (Query Result Message)

A TEXT value. This is the message, the **second column**, produced by the most recent execution of the **ISOK_QUERIES.Query**.

4.2.13 QR_Extra (Query Result Extra JSON data)

A **JSONB** value. The value of the third, optional, column returned by most recent execution of the query. This may contain any JSON deemed useful. This column serves as a catch-all container for any additional data that needs to be tracked regarding a reported condition.

The value of this column may be NULL. This is the default when the **ISOK_QUERIES.Query** does not return a third column.

See PostgreSQL's documentation on **the JSON data types** for information on how to access, index, and efficiently query the **JSONB** data type.

4.2.14 Notes

A TEXT value. Any notes regarding this particular query result. This column may not be NULL. This column may be empty; it need not contain characters, but it may not contain only whitespace characters.

5 Isok Support Tables

Support tables are used to control the values used in other tables. Each support table has a key, with an appropriate column name, and a column named `Description`. Both of these columns are of type TEXT. The keys of the support table are foreign keys of a column which has a controlled vocabulary, a limited number of terms which are allowed to be used.

An administrator can add or remove rows from the support tables to dynamically control the allowed vocabulary.

The support table `Description` columns must be unique when the comparison is made in a case-insensitive manner.

5.1 IQ_TYPES (Integrity Query Types)

IQ_TYPES contains one row for every code used to classify database integrity queries. Classification may be by the type of data integrity problem the related queries are designed to uncover, by who is responsible for resolving the discovered problems, or any other desired classification scheme.

5.1.1 Key: IQType

The IQ_TYPES table is keyed by the IQType column. This column may not contain whitespace characters. This column must be unique when compared in a case-insensitive fashion.

5.2 IR_TYPES (Isok Result Types)

IR_TYPES contains one row for every code used to classify or explain sets of database integrity problems, problems discovered by Isok's queries. Codes may be used as needed, whether to organize reported problems pending resolution, to describe the circumstances which resolve an issue, or to serve other purposes.

5.2.1 Key: IRType

The IR_TYPES table is keyed by the IRType column. This column may not contain whitespace characters. This column must be unique when compared in a case-insensitive fashion.

6 The Isok Functions (Activating Isok)

Isok is run by using one of its functions. Of course the **ISOK_RESULTS** table may always be queried manually, but this does not discover any new problems.

All of the Isok functions are designed to be used in the **FROM** clause of **SELECT** statements, as if they were tables. Indeed the functions look like tables to the **SELECT** statement, tables that look exactly like **ISOK_RESULTS** -- except that the **Resolved** column is missing. The difference between querying on the **ISOK_RESULTS** table directly and querying using Isok's functions is that the functions update the content of the **ISOK_RESULTS** table by executing the queries in **ISOK_QUERIES** table. Also, the functions never return rows where the underlying **ISOK_RESULTS** row has a non-NULL **Resolved** value or a **Deferred_To** time and date that has not yet been reached.

All timestamps, date plus time values, which Isok updates in the **ISOK_QUERIES** and **ISOK_RESULTS** tables are set to the date and time at which program execution started. So when, say, **run_isok_queries()**, is run, all of the new timestamp values in the **ISOK_QUERIES** and **ISOK_RESULTS** rows touched by the execution are identical.

Various Isok functions (or versions of the same function) are supplied to allow easy selection of which queries in which **ISOK_QUERIES** rows are to be executed, whether all or only some.

Note

As with a regular table, the order in which rows are returned by Isok's functions is unspecified. If you wish to ensure a specific ordering an **ORDER BY** clause must be used.

6.1 run_isok_queries

run_isok_queries — execute one or more of the queries stored in the **ISOK_QUERIES** table

Synopsis

```
TABLE (irid, iquery, first_seen, last_seen, category, qr_id, qr_message, notes) run_isok_queries (void);  
TABLE (irid, iquery, first_seen, last_seen, category, qr_id, qr_message, notes) run_isok_queries (  
TEXT iquery );
```

Input

iquery

The text of an SQL query. The query must return a single column of **ISOK_QUERIES.IQuery** values.

Description

A function which runs the queries stored in the **ISOK_QUERIES** table, returns the output of the stored queries, and stores the results in the **ISOK_RESULTS** table. Because the function returns rows and columns it must be invoked in the **FROM** clause of a **SELECT** statement. (See the **Examples** below.)

The function may be called in one of two ways. When called with no arguments all of the queries in **ISOK_QUERIES** are run. When called with the text of an SQL query, a query which returns a single column containing **ISOK_QUERIES.IQuery** values, the function runs only those queries.

Tip

Use PostgreSQL's **dollar quoting** when supplying a query to **run_isok_queries()**.

The function returns a set of columns with multiple rows, a table. So it is expected to be used in the **FROM** clause of a **SELECT** statement. The columns returned by the function are the columns of the **ISOK_RESULTS** table, excepting the **Resolved** column.

The rows returned by the function are those of the newly updated **ISOK_RESULTS** table, excepting those rows with a non-NULL **Resolved** column or those rows with a **Deferred_To** value that is in the future. Only

those rows that are related to the executed queries (in **ISOK_QUERIES**) are returned. So, when called with no arguments the function returns all warnings that have not been resolved and all errors. When called with a query that selects specific **ISOK_QUERIES** to execute, only the unresolved warnings and errors discovered by the executed **ISOK_QUERIES** are returned.

The Record of Query Execution

Running an **ISOK_QUERIES.Query** does more than add new rows to the **ISOK_RESULTS** table. Updates are made to existing rows to record and track the query execution's results.

The **ISOK_QUERIES.Last_Run** value is updated.

On **ISOK_RESULTS**, the rows to update are found by matching the **ISOK_RESULTS.IQName** value with the **ISOK_QUERIES.IQName** of the executed query, while also matching the **QR_ID** value with the value returned in the first column of the executed query. The columns updated are: **Last_Seen** , **Last_Role** , **Last_Schemas** , **QR_Message** , and **QR_Extra**.

Because the record of the results produced by Isok queries are updated, a query may be refined over time to produce enough information to resolve the reported issues.

Even though the execution of **run_isok_queries()** does not return rows that are **resolved**, all rows returned by an executed query have all the aforementioned columns updated to new values. Whether a row is returned or not does not matter, the update occurs anyway.

Deletion of Old Results

If an existing **ISOK_RESULTS** row matches the **IQName** value of the executed query and there is no corresponding **QR_ID** value returned by the executed query, and the value of **ISOK_RESULTS.Keep_Until** is either **NULL** or **CURRENT_TIMESTAMP**³ is not earlier than **ISOK_RESULTS.Keep_Until** then the **ISOK_RESULTS** row is deleted. This empties the **ISOK_RESULTS** table of errors and warnings that no longer apply to the current state of the database.

If the query returns warnings, this deletion behavior does not depend upon whether or not the warning is resolved.

Examples

The following example runs all the queries in **ISOK_QUERIES**, displays all the errors and all the unresolved warnings (unless the error or warning has been deferred), ordered first by the name of the query, within that showing newer problems first, and within that ordered by warning id.

³The time the current transaction started, which, if a transaction was not explicitly started, is the time the database engine received the current SQL statement from the client and began execution.

Example 6.1 Executing all ISOK_QUERIES

```
SELECT *
  FROM run_isok_queries() AS problems
 ORDER BY problems.iqname
        , problems.first_seen DESC
        , problems.qr_id;
```

The following example runs a single saved query with an **ISOK_QUERIES.IQName** of mycheck and displays any of these sorts of problems found, ordered as in the previous example. This example also demonstrates how to use **dollar quoting** to give a query to **run_isok_queries** and thereby avoid problems having to do with trying to nest regular quotes.

Example 6.2 Executing a single ISOK_QUERIES.Query

```
SELECT *
  FROM run_isok_queries($$SELECT 'mycheck'$$) AS problems
 ORDER BY problems.iqname
        , problems.first_seen DESC
        , problems.qr_id;
```

The following example runs multiple specific queries, those with an **ISOK_QUERIES.IQName** of mycheck, yourcheck, and theircheck, and displays any of these sorts of problems found, ordered as in the previous example. As before, **dollar quoting** is used to quote the query which produces the **IQNames**.

Example 6.3 Executing many specific ISOK_QUERIES.Query-s

```
SELECT *
  FROM run_isok_queries($$VALUES ('mycheck')
                                , ('yourcheck')
                                , ('theircheck')$$) AS problems
 ORDER BY problems.iqname
        , problems.first_seen DESC
        , problems.qr_id;
```

The following example runs all the queries of the **bdate** type and displays any of these sorts of problems found, ordered as in the previous example. Again, **dollar quoting** is used.

Example 6.4 Executing ISOK_QUERIES of the “bdate” type

```
SELECT *
  FROM run_isok_queries(
    $$SELECT isok_queries.iqname
```

```
        FROM isok_queries
        WHERE isok_queries.type = 'bdate'$$
    ) AS problems
ORDER BY problems.iqname
        , problems.first_seen DESC
        , problems.qr_id;
```

A Security Considerations

The security concerns surrounding Isok are many, and can be complex. Fundamentally, this is because Isok executes arbitrary SQL. If the wrong SQL is executed, in the wrong context, anything might happen to your data. This appendix identifies pertinent issues, and how to minimize risk.

Ultimately, these are the same issues that arise in any application that executes SQL. The big difference between Isok and other applications is that most applications execute a more-or-less limited number of SQL queries that are carefully crafted to suit a specific purpose. The queries executed by Isok can have much more variation, and be subject to less review.

In the end, the recommendations here come down to following generally accepted security best-practices, in particular, the [principle of least privilege](#).

A.1 Limiting Access

Limiting access to Isok is a clear first-step. Installing Isok into a dedicated [schema](#) goes a long way toward helping with this. When a schema is created, only the owner has access.⁴ So, unless **GRANTS** are issued, access is limited by default.

Remember also, the **ISOK_RESULTS** table contains query output that may contain sensitive information to which access should be restricted. And, even if this is not true today, it may become true when additional queries are added to **ISOK_QUERIES**.

Even the queries in **ISOK_QUERIES** could, possibly, contain sensitive information.

A.2 What Queries Access Matters

The executed queries, the **ISOK_QUERIES.Querys**, can be any SQL statement. Obviously, what executes matters. Less obviously, the ownership of and permissions granted on every object referenced by every query also matters.

⁴Yes, this is true of all objects. Only the owner has access to any newly-created object. But having a single point of access, the schema dedicated to Isok, that grants access to all of Isok, provides a very useful point of control that serves as an easily audited gateway to Isok's functionality.

Really, when multiple schemas are in the `search_path`, it is the ownership of and permissions granted on every object that *might be* referenced by every query that matters.

The ownership and permissions of referenced objects matter because these factors ultimately control what any given query actually does. If a user has, for example, permission to alter a view with some given name, or replace a table having that name with a view that has the same name, then the user can change what happens when that name is used in a query. The user can write a view that does anything. Or at least anything that the role which runs `run_isok_queries()` is allowed to do.

Imagine, the new view could call a function, say, in place of a table that was referenced, and that function could do anything at all. Even while still returning the replaced table's rows, so as to produce a results identical to that produced before the system was altered.

That is the issue. The user executing the saved query is dependent upon the goodwill of all the users who have enough access to alter any of the objects involved when the query is executed.

A.3 The Search Path

The `ISOK_QUERIES.Search_Path` column allows setting of the `search_path` on a per-query basis. The security implications of changing the `search_path` may be the hardest to reason through. The crux of the problem is that different users may have different permissions on the search path's schemas, and on the objects the schemas contain. This opens up the possibility that a malicious user may create an object, say, a view or a function, in a schema which appears earlier in the search path than the schema holding the object the query expects to find. If this is the case, the query will use the malicious object instead of the expected object.

The PostgreSQL documentation contains an analysis of this situation, in the context of writing `SECURITY DEFINER` functions. However, the analysis in the PostgreSQL documentation is not entirely applicable to Isok. In the case of Isok, even when Isok changes the effective role, the position in the search path of the temporary table schema, `pg_temp`, is less relevant. Because temporary tables are not shared between connections, the creation of a malicious object in the temporary schema must be done in the current connection. And so the issue is no different from that which occurs when any other malicious object is created in the current connection. In either case, there is a security lapse that occurs dynamically, at some point in the current connection.

Having said that, moving `pg_temp` to the end of the search path does make it harder to “mask” an existing object with a malicious object. Because all roles have permission to create objects in `pg_temp`, a malicious actor would not be able to mask an existing object with an object in `pg_temp` if `pg_temp` is at the end of the search path. For this reason it may make sense to always put `pg_temp` at the end of the search path whenever Isok is used.

The PostgreSQL documentation's observation remains valid: Malicious users with the ability to change objects in the search path may inject malicious objects.

A.4 Roles

The role in effect does have security implications. But changing a role for the duration of a query's execution, with `ISOK_QUERIES.Role`, has fewer security implications than it might seem.

Changing the current role does open up the possibility that database objects to which the new role has access may be changed. But this door is already open. A new role cannot be assumed without some chain of SET option grants from the `session_user` [definition [here](#)(-ish)] to the current role. So a malicious actor always has access to the same set of roles, regardless of whether Isok is involved or not.

What might be surprising is that, even though a role may **SET ROLE** to another, perhaps with less privileges, it is always possible to use **RESET ROLE** (or **SET ROLE NONE**) and reset the current role to the `session_role`. There is no sandboxing. If the session sets a role before running `run_isok_queries()`, there is the possibility that a malicious actor might undo the assumption of the role. This could then affect the role used to execute any queries that `run_isok_queries()` has not yet executed.

Don't expect that a **SET ROLE** to a role of lesser privileges makes running `run_isok_queries()` any safer.

A.5 Mitigation Strategies

There is no one-size-fits-all solution. Even **disabling** Isok's ability to dynamically alter the current search path and the current role does not address the fundamental issues. Even more so because, to be useful, `run_isok_queries()` may need an expansive set of permissions to do its job.

One possible strategy is to always supply values in the `ISOK_QUERIES.Role` `ISOK_QUERIES.Search_Path` columns. At least that way the context of each query's execution is always known.

Another possible strategy is to install Isok in multiple schemas, each schema dedicated to a different purpose and assigned different permissions, intended to be used by different users.

A.6 Creating an Audit Trail

To better respond to a suspected security problem it is always very useful to have an audit trail to examine. One way to have such a trail is to install a **temporal extension**. These extensions track the history of database content over time. The Isok tables could be temporally tracked, to audit what queries were changed when, as well as what query results were produced or deleted when.

A conceivable, although entirely untested on our part, idea is to use a temporal extension to track changes made to the `postgres` database. Otherwise known as the system catalog, `pg_catalog`, this database contains the definitions of all objects in all databases. Tracking the catalog provides an audit trail should a malicious object be created, although this would not help if `pg_temp` was involved.

Some installations may even want to temporally track all their tables, although this may not be feasible for a whole host of reasons.

B Local Copies of the Documentation

When Isok is installed as an **extension**, local copies of the documentation are installed. The **pg_config** PostgreSQL client command provides an easy way to find the documentation.

Example B.1 Finding the Documentation of Locally Installed Extensions

```
$ printf '\nExtension documentation is located in:\n%s\n\n' $(pg_config -- \↵
docdir)/extension/

Extension documentation is located in:
/usr/share/doc/postgresql-doc-15/extension/

$ ls $(pg_config --docdir)/extension
pg_isok--1.0.0.config pg_isok_html pg_isok_usletter.pdf
pg_isok_a4.pdf        pg_isok.txt

$ printf '\nThe URL used to read the local HTML documentation is:\nfile \↵
://%s\n\n' \
    $(pg_config --docdir)/extension/pg_isok_html/html_paginated/index \↵
    .html

The URL used to read the local HTML documentation is:
file:///usr/share/doc/postgresql-doc-15/extension/pg_isok_html/ \↵
html_paginated/index.html
```

C Periodic Execution

A monitoring system must periodically execute and deliver reports if it is to monitor and provide actionable alerts on an ongoing basis. Isok does not include a periodic job scheduler. Tools like the Unix cron command, the systemd timer system, or the PostgreSQL **pg_cron** extension are useful to automate, and make periodic, Isok's monitoring. There are plenty of job schedulers available and one of these must be used to schedule the production of Isok's reports.

Typically, something must deliver the reports Isok produces, because push-notifications remind people to act. Although Isok does archive the reports it produces, it does not include a report delivery mechanism. Email, or other push-based delivery mechanisms (perhaps email-to-SMS text gateways), are the expected delivery mechanisms for Isok's reports. Isok itself can report to standard out when run from **psql**. Depending on your job scheduler, some amount of scripting may be required to route Isok's reports to a push delivery service.

C.1 Example Periodic Reporting via Email Using systemd

The files shown below deliver an Isok report, if there is something to report, by email every Tuesday morning.

The system on which they are installed must have a **mail transfer agent** installed, like **Postfix**, to begin the email delivery process. The system also must have **GNU mailutils** installed, or an equivalent **mail** command, like BSD **mailx**, to send the email.

Most operating systems will have packages available to install these services, and a way to configure simple defaults. However, it is non-trivial to reliably deliver email from your system directly to the rest of the Internet. The recommended approach is to send the email from your local system to a *mail relay* provided by your local IT professionals. (Or, your Internet Service Provider. Or, if you are hosted in the cloud, contact your hosting company.) These professionals will usually be able to supply you with what you need to know to have mail sent from your system to a system able to send email to the Internet at-large. If not, there are companies that provide this service for a nominal fee.

The service you would ask for is usually called *an email relay service*.

It is usually a good idea to ask your local IT professionals to help with the selection of a mail transfer agent.

This example is expected to run, as is, on most systems that have the default **PostgreSQL** install.

The example assumes that **pg_hba.conf** contains:

```
local    all                postgres                                ←
peer
```

This line is typically present, but this is not guaranteed.

Example C.1 Sample /usr/local/bin/pg_isok_report File

```
#!/usr/bin/bash
#
# Run pg_isok, and mail (with GNU mailutils) if it produces anything.
#
# Expected environment variables:
# CONNECTION_STRING
#   The postgres connection string (or other arguments)
#   Putting passwords in here is a bad idea, change pg_hba.conf instead?
# ISOK_SCHEMA
#   The schema in which pg_isok is installed
#
# The recommendation is to not change this.  Instead, make an
# alias for "pg_isok_report" in /etc/aliases.
MAIL_RECIPIENT=pg_isok_report

EMPTY_FILE=$(/usr/bin/mktemp --tmpdir pg_isok_empty.XXXXXXXXXX)
```

```

OUTPUT=$( /usr/bin/mktemp --tmpdir pg_isok_output.XXXXXXXXXX)

PSQL="/usr/bin/psql ${CONNECTION_STRING}"

cleanup () {
    /usr/bin/rm -rf ${EMPTY_FILE} ${OUTPUT}
}
trap cleanup EXIT

PAGER= ${PSQL} --command="
        SELECT irid, iqname, first_seen, last_seen, last_role
           , last_schemas, deferred_to, category, keep_until
           , qr_id, qr_message, qr_extra, notes
        FROM ${ISOK_SCHEMA}.isok_results
        LIMIT 0;

    " \
    > ${EMPTY_FILE} 2>&1

PAGER= ${PSQL} --command="SELECT * FROM ${ISOK_SCHEMA}.run_isok_queries() ↵
; " \
    > ${OUTPUT} 2>&1

cmp --quiet ${EMPTY_FILE} ${OUTPUT} \
|| { /usr/bin/mail -s 'Isok output' ${MAIL_RECIPIENT} \
    < ${OUTPUT} ; }

```

Example C.2 Sample /etc/systemd/system/isok_report.timer File

```

[Unit]
Description=Tuesday report from pg_isok

[Timer]
# See: man 7 systemd.time
OnCalendar=tuesday *-*-* 3:00
RandomizedDelaySec=60m
Persistent=true

[Install]
WantedBy=timers.target

```

Example C.3 Sample /etc/systemd/system/isok_report.service File

```

[Unit]
Description=Run pg_isok's run_isok_queries() function and email when there ↵
's\

```

```
a result
ConditionACPower=true

[Service]
#
# Configuration is done here (and in /etc/aliases, see pg_isok_report)
#

# The postgres connection string (or other arguments to psql)
# Putting passwords in here is a bad idea, change pg_hba.conf instead?
Environment="CONNECTION_STRING=mydatabase"

# Put a connection string variable assignment containing secrets in this ↵
#   file:
# (man 5 systemd.exec)
#EnvironmentFile=/etc/pg_isok_secrets

# The schema in which pg_isok is installed
Environment="ISOK_SCHEMA=isok"

# End of configuration

# The Unix user running the db engine
# (Expected to be the same as the PostgreSQL bootstrap superuser)
User=postgres
Type=oneshot
KillMode=process

PassEnvironment=CONNECTION_STRING ISOK_SCHEMA
ExecStart=/usr/local/bin/pg_isok_report
```

After installation, don't forget to run:

```
systemctl daemon-reload
systemctl enable pg_isok_report.timer
systemctl start pg_isok_report.timer
```

D Techniques For Making Local Extensions to Isok

Should you find yourself wishing that Isok did more, here are some suggested techniques for extending the functionality of your Isok instance. There is overlap, more than one technique may facilitate reaching any given goal.

D.1 Wrap `run_isok_queries()`

To perform actions before or after execution of `run_isok_queries()`, write a new function that takes `run_isok_queries()`'s arguments and returns `run_isok_queries()`'s results. And does what you wish before or afterward.

So, for example, to ensure a safe, consistent, value for `search_path`, you could write a function that executes `SET search_path ...;`, before itself calling `run_isok_queries()` and returning the result.

D.2 Extend Issue Classification

If you would like additional ways to classify the issues your queries discover, the `IR_TYPES` table may be extended.

Create your own table to do this, called, say, `IR_TYPE_CLASSES`.

The key of this table is that of the `IR_TYPES` table; may as well call it `IRType`. It is a foreign key, referencing `IR_TYPES`. So your new table has a one-to-one relationship with `IR_TYPES`.

Add as many columns as you like to your new table, a column for each (orthogonal) sub-category by which you would like to classify reported issues. Boolean columns behave as a tag, toggling classification. Other kinds of columns, possibly containing foreign keys to control the vocabulary used, allow richer classification schemes.

D.3 Fully Utilize `ISOK_RESULTS.QR_Extra`

Indexing the `JSONB ISOK_RESULTS.QR_Extra` column improves performance.

If you know your `JSONB` keys, you can make a `VIEW` that exposes the value of those keys as the view's columns. Users of this view would not have to be familiar with querying `JSONB`.

More complex schemes involve putting a `row-level BEFORE trigger` on `ISOK_RESULTS` to distribute the various values appearing in `ISOK_RESULTS` into other tables. But doing so surely takes you past the point of diminishing returns. It is easier to `modify the SQL that Isok installs`. And doing so is probably also less of a long-term maintenance burden, which matters.

D.4 Modify Isok's Generated SQL

Should you want to make a modification like allowing the queries in `ISOK_QUERIES.Query` to return additional columns, you can do so by modifying the SQL that Isok loads.

Isok is pure SQL, so `the SQL can be generated` and then modified, in any way you like, before `being loaded` into a database's schema.

E Developing Isok

We consider Isok to be feature complete. That said, there's always room for improvement and contributions are welcome. Never the less, if you would like your changes added to Isok, before doing a lot of work we recommend communicating with us.

You are, of course, free to **make changes to your local Isok**.

Development should be done by cloning the git repository.

E.1 Tool Requirements

Isok uses the **PGXN.org tools** for building and distribution, which in turn uses parts of the **PostgreSQL GNU make-based build system**. So GNU make is required. In addition, the Isok documentation is done with the **DocBook**, as is **PostgreSQL's**, so the tooling required to build the documentation is **the same as PostgreSQL**, although Isok currently generates XHTML so may require a slightly different set of DTDs.

Aside from these requirements, the following additional tools are needed:

DBLatex The DocBook to LaTeX to PDF, etc., converter

gawk The GNU awk implementation

Gnu m4 The macro pre-processor used by GNU autoconf, etc.

links The command-line web browser

xmllint The XML linter

zip The archive and compression tool

DBLatex also requires the installation of various TeX and LaTeX tooling, which your O/S's package manager is likely to install as a dependency.

When working with DocBook, the book **DocBook XSL: The Complete Guide** from **Sagehill.net** may also be useful.

E.2 Building and Distributing

Run **make help** for help on the Makefile targets.

Almost all the generated files are included in the distribution. This is so that the user, or the PGXN tooling, can use the Makefile for installation, and uninstallation, without having to have all the tooling required for development installed.

F Acknowledgments and History

Isok was first developed as "The Warning System" for the [Gombe Mother Infant Database Project](#). It was later incorporated into [Babase](#), part of [The Amboseli Baboon Research Project](#), and enhanced to take advantage of the features in [PostgreSQL 9.1](#). Further enhancement, including release as a [PostgreSQL](#) extension, was done for [The SokweDB Project](#), developed by [The Jane Goodall Institute](#).

We would like to thank these projects, and their funding sources, for enabling the development and release of Isok.

The acknowledgments included in the above projects' documentation are reproduced below. (Verbatim, excepting some updated contact information.) It is not clear how applicable the entirety of the acknowledgments are, but we would rather be overly generous in our thanks than be stingy.

The following acknowledgments do not include all the people who have enabled and assisted Isok development. You know who you are. Thank you. And thanks to the larger Open Source community. Without their support, and hard work, none of this would have happened.

F.1 The Gombe Mother-Infant Project Acknowledgments

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⁵See: [Estimating the Total Development Cost of a Linux Distribution](#).

Any opinions, findings, conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Institutes of Health, The Leo S. Guthman Foundation, the Lincoln Park Zoo, Franklin & Marshall College, The George Washington University, or any other organization which has supplied support for this work.

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Any opinions, findings, conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation, the National Institute of Aging, the Princeton Center for the Demography of Aging, the Chicago Zoological Society, the Max Planck Institute for Demographic Research, the L.S.B. Leakey Foundation, the National Geographic Society, or any other organization which has supplied support for this work.

F.3 The SokweDB Acknowledgements

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Any opinions, findings, conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of Microsoft.

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