Transparent SOFIA
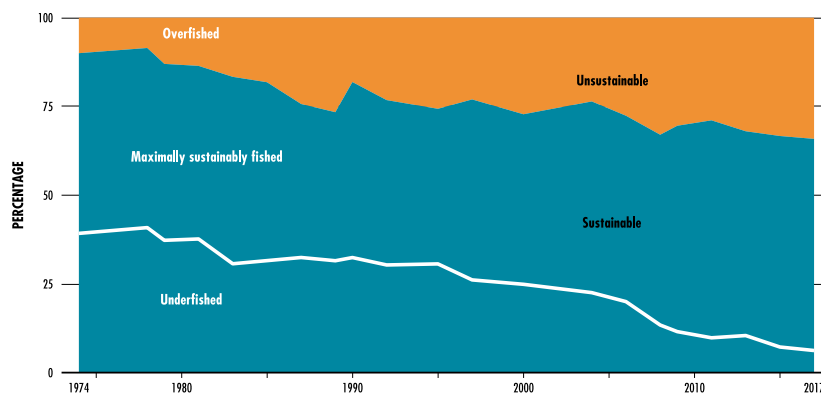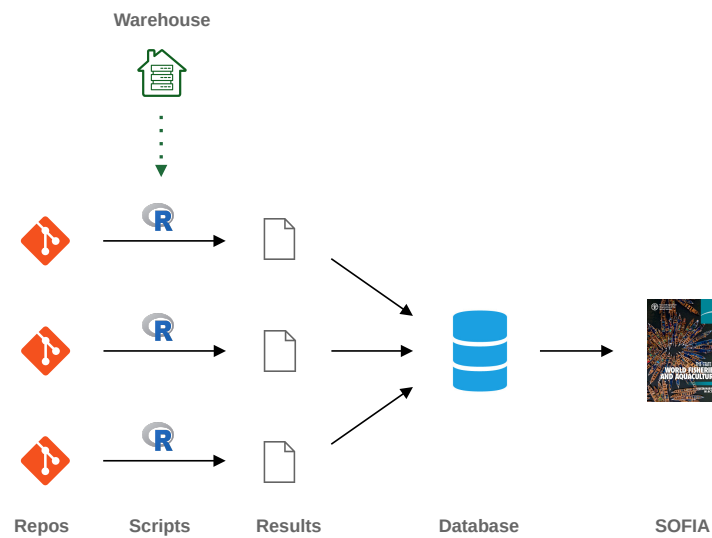# Analytical Framework (TSAF)

Design and development progress

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Contents

1 Executive summary

This report gives a brief overview of the design and development progress of the new Transparent SOFIA Analytical Framework (TSAF) that was initiated in March 2021. As of December 2021, the design is nearly complete and the implementation is underway. The overall framework consists of four components:

- TSAF repositories, where each repository contains one analysis, calculating the status of stocks in a given area.
- Input data warehouse, with fisheries data for all areas and stocks.
- R package, a collection of utilities that are commonly used in TSAF analyses.
- Database, storing the results from all TSAF analyses.

At the end of this report is an appendix, listing Arni Magnusson's contributions in 2021 to TSAF design and development.

2 Introduction

2.1 Background

In March 2021, Rishi Sharma contacted Arni Magnusson to explore the possibility of collaboration to design a new way to organize the analysis of the State of the World Fisheries and Aquaculture (SOFIA). From his years at ICES, Arni had experience in designing the Transparent Assessment Framework (TAF, ICES 2021) which is used to organize the stock assessment and advisory workflow for a large number of ICES stock assessments each year.

The first exploratory step was to convert an existing SOFIA analysis, from a single monolithic R Markdown document to TAF format, using Area 37 as a prototype. This was done by creating a GitHub repository and splitting the analysis into four R scripts: `data.R`, `model.R`, `output.R`, and `report.R`. Splitting the analysis in this way into discrete steps made it more manageable, easier to maintain and modify. The TAF format also provides improved data provenance, tracking what each input data file contains and where the data came from.

The next step was to make incremental improvements in the R code and to give objects and files short and generic names that are consistent between different SOFIA analyses. The prototype analysis of Area 37 was then presented in April 2021 to the FAO team overseeing the SOFIA analysis, Pedro Barros and colleagues, for feedback and direction.

Having completed the prototype, it was time to research and develop an efficient and practical way to organize a large number of SOFIA analyses in a similar way, and then summarize the results to the level presented in the SOFIA report (FAO 2020). A TSAF development team was formed, consisting of Rishi Sharma, Arni Magnusson, and Nicole Tursich, with regular meetings and close technical collaboration.

2.2   Objectives

It is not for this author to define or prioritize the objectives of TSAF to support the overall analysis behind SOFIA. However, the following topics are worth mentioning, as a context for some of the design decisions and features that are being developed.

Efficiency is the ability to edit code in a single place to modify a large number of analyses, and to calculate top-level summary statistics from a large number of analyses.

Clarity is the ability to easily navigate to a specific part of the analysis of a particular stock group and area, and to look up a specific result from one or more analyses.

Traceability is the ability to backtrack exactly how a specific result was calculated, such as the status of a particular stock group in a given area.

Open science is the ability to make the R scripts available online, along with the input data required for the scripts to run, inviting peer review of methodology and scientific collaboration.

Reproducibility is the ability to run analyses on a variety of computers, e.g., a personal Windows laptop or a high-performance Linux cluster, to get the exact same result — also when the analysis is rerun months or years later.

Quality assurance is the design and adoption of a workflow that reduces the probability of making human mistakes when preparing, modifying, running, and postprocessing the results from analyses.

Quality control is the ability to identify where a human mistake has been made in a given analytical process, so the mistake can be located and corrected.

The initial development of TSAF has focused especially on Tier 2 cases of SOFIA analyses, where official stock assessments are not available, but catch and effort data exist as a basis for estimating stock status using data-limited methods.

The TSAF design also aims to serve as a platform to organize Tier 1 analyses (deriving stock status from official stock assessments) as well as Tier 3 analyses (deriving stock status estimates from expert elicitation). These tiers will require less R code than Tier 2 but use the same structure for R scripts and data provenance to document exactly how the stock status was calculated.

2.3   Project management

A project board (https://github.com/sofia-tsaf/project) is used to track TSAF development progress, along with a discussion board, milestones, and issue tracker.

3 Design

The TSAF design (Figure 1) is based on repositories containing R scripts that read input from a data warehouse to estimate stock status. These results are then stored in a dedicated TSAF database, which serves as the foundation for calculating summary statistics for the final SOFIA report.
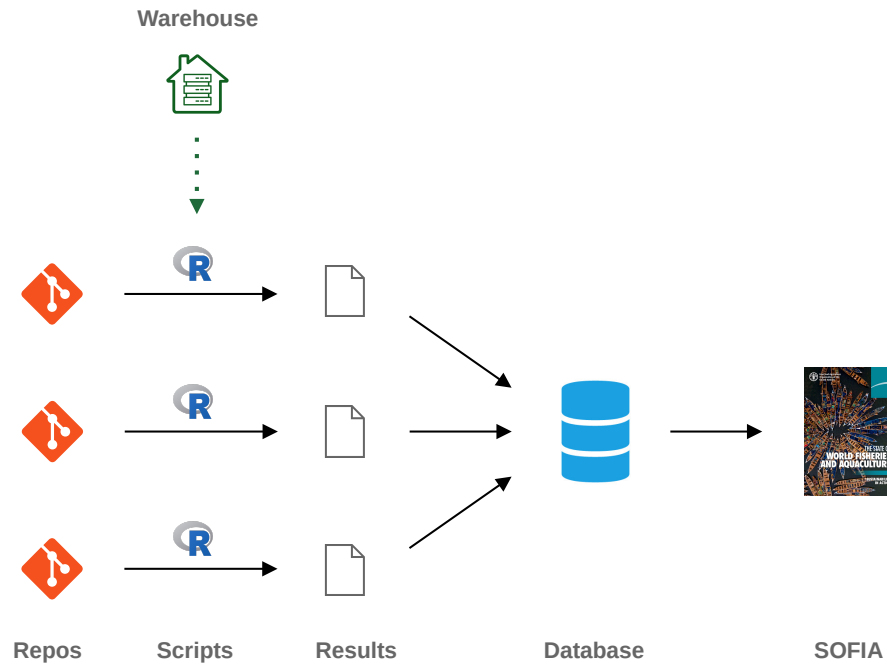

Figure 1. TSAF diagram, showing the flow of information from individual repositories (analyses of stocks and areas) to the final SOFIA report.

The scripts use a dedicated R package called TSAF. The next sections describe each component of the TSAF design in some detail: repositories, input data warehouse, R package, and the database.

3.1 TSAF repositories

3.1.1 Repository features

Each TSAF repository is a unit of analysis, corresponding to a specific area and stocks. A GitHub repository, sometimes abbreviated as 'repo', is an online directory that is especially convenient for organizing text files, such as scripts and data files. GitHub repository features relevant for TSAF include:

- Ability to make scripts available online, for browsing and downloading, along with the input data required for the scripts to run.

- Automatic backup of all files with the ability to return to previous saved states.

- Tracked changes showing who changed what and when, supporting online teamwork.

- Ability to tag specific saved states of the analysis and give them descriptive names, such as 'starting point', '2021 data' or 'results imported to database'.

- Ability to upload large attachments (>100 MB) to accompany tagged states.

- Online facilities to compare text files and view changes, line by line.

3.1.2 R scripts

The analysis inside each repository consists of a set of R scripts that are organized in TAF format (Magnusson and Millar 2021). This means there are four standard scripts (Table 1) that conduct and document the analysis:

Table 1. Standard TAF scripts for a given analysis.

Script	Purpose
data.R	Preprocess data, write TAF data tables
model.R	Run analysis, write model results
output.R	Extract results of interest, write TAF output tables
report.R	Prepare plots and formatted tables

The TAF scripts are run sequentially, each reading files that were created in a previous step. The first script, data.R, reads data files that were declared and documented in a DATA.bib text file. A similar SOFTWARE.bib file can be used to declare specific versions of software used in the analysis, to strengthen reproducibility.
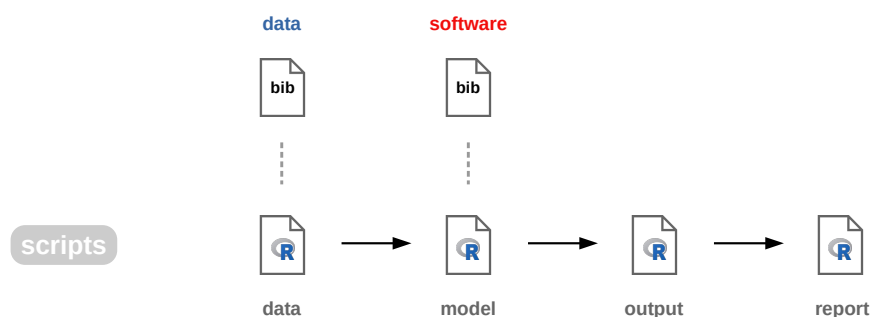

Figure 2. TAF scripted workflow. Each TSAF repository/analysis contains four standard R scripts that are run sequentially. The initial data and software are declared in so-called bib files.

The R scripts conducting TSAF analyses rely especially on three R packages:

- TSAF – a new dedicated package to support TSAF
  (Sharma and Magnusson 2021)

- TAF – utilities to manage scripts, data files, metadata, and R data objects
  (Magnusson and Millar 2021)

- sraplus – biomass dynamics model with Bayesian priors
  (Ovando 2019)

3.1.3 Repository names and directory structure

GitHub repositories are given descriptive names, such as

https://github.com/sofia-tsaf/2021Area37Coastal

for the analysis conducted in 2021 of coastal stocks in Area 37.

On a personal laptop or a high-performance cluster, the TSAF repositories are organized in a hierarchical directory structure (Figure 3), similar to the repository name as year/area/stock group.

Remote repository

https://github.com/sofia-tsaf/2021Area37Coastal

Local directory structure

📁 **2021**
  📁 **37**
    📁 **coastal**
      Ⓡ data.R
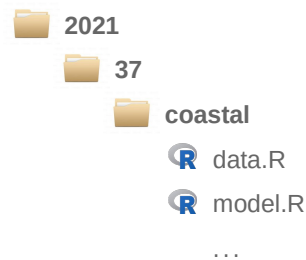   Ⓡ model.R
      …

Figure 3. TSAF local directory structure, showing the similarity between the remote repository name and the local directory names.

This hierarchical directory structure is practical to navigate and run the analyses, access results, and run top-level summary calculations across a large number of analyses.

3.2 Input data warehouse

The input data warehouse contains fisheries data for all areas and stocks. For TSAF analyses of Tier 2 stocks, the focus is on catch and effort data, which are organized in two GitHub repositories:

https://github.com/sofia-tsaf/catches

https://github.com/sofia-tsaf/effort

Individual TSAF analyses start by reading catch and effort data from the data warehouse. In this way, the input data for all analyses are stored in one central place, where they can be updated, documented, and quality checked.

3.3 R package

The TSAF package (Sharma and Magnusson 2021) contains utilities that are commonly used in TSAF analyses. It is developed in a dedicated GitHub repository:

https://github.com/sofia-tsaf/TSAF

The TSAF package provides a single place to modify a large number of TSAF analyses. Incremental improvements become more manageable, e.g., changing the format of a specific plot, without having to edit each and every TSAF analysis. It also makes the R scripts for each analysis shorter and thus easier to read, write, and maintain.

3.4 Database

The TSAF database will contain the results from all the individual TSAF analyses. The primary focus of the database is on stock status, both in numerical terms and in categorical terms: underfished, fully fished, and overfished.

The database is the central node and key component of the TSAF design. The only way to enter data into the database is via TSAF analyses, as indicated in the TSAF diagram (Figure 1), and when TSAF analyses of a specific areas and stocks are updated, the database is automatically updated. Furthermore, the top-level analysis for the final SOFIA report, aggregating a large number of TSAF analyses, should be based on queries to the database.

The above design guarantees the traceability of SOFIA results, all the way from the individual datasets and analyses to the final published report.

The database is also a convenient stage in the pipeline to apply quality control. Examples of quality checks could include referential integrity of species and stock names, summary statistics at different levels of aggregation, counting stocks in each area, plotting the distribution of numerical stock status, etc. This will ensure that all stocks are accounted for, and reveal any inconsistencies or issues that should be checked in the underlying analyses.

4 Development status and next steps

4.1 TSAF repositories

4.1.1 Current status

As of end of December 2021, the GitHub site https://github.com/sofia-tsaf contains 12 TSAF repositories:

```
area31
area37
2021Area37Clams
2021Area37Coastal
2021Area37Cods
2021Area37Demersal
2021Area37Flounder
2021Area37Herring
2021Area37Other
2021Area37Shads
2021Area37Shrimps
2021Area37Squid
```

The status of all of these analyses is exploratory for development purposes, as opposed to production analyses for a final SOFIA report.

The initial step in TSAF development focused on `area31` and `area37`, which are aggregated analyses where all stocks within an area share the same annual effort series, as well as priors on historical and current stock status. These prototype analyses proved valuable to test and extend the early TSAF design.

In the next step of TSAF development, the analysis of Area 37 was divided into stock groups (clams, costal, cods, etc.), allowing stock groups to have different effort series and priors.

The current TSAF development focuses on allowing full detailed control in the analysis, where each species within a stock group can have different effort series and priors. To manage these model settings, new R functions were developed called `addEffort` and `addDriors`. Encapsulating these actions in functions, that are defined and maintained outside the main scripts, also comes with the side benefit of shortening and simplifying the scripts. These latest developments have used the `2021Area37Coastal` analysis as a test case.

4.1.2 Next steps

Read from input data warehouse

Currently, the TSAF analyses read the initial catch and effort data from a local data directory, specific to each analysis. This means that data are repeated between analyses, especially the effort data. Furthermore, to update catch and effort data,

one would have to modify a large number of TSAF repositories. The input data warehouse offers a more efficient, traceable, and quality-controlled workflow.

Categorical status by stock and year

Currently, the TSAF analyses produce an output file called `stock_timeseries.csv` with numerical B/B_{MSY} and F/F_{MSY} by stock and year. For the subsequent analysis, it would be beneficial if the categorical stock status (underfished, fully fished, overfished) by year is also included in this file. This improvement will require modifications to the `output.R` script of all TSAF analyses.

Standardize and shorten scripts

The main difference between the TSAF analyses that have been developed so far is the underlying catch and effort data. Other model input, such as priors, is also specified in dedicated input files. The benefit of this design is that the analytical scripts (`data.R`, `model.R`, `output.R`, and `report.R`) are almost identical between different TSAF repositories.

As the number of TSAF repositories grows, it becomes more cumbersome to make the same change across all analyses. A simple change, such as a minor improvement in the format of a specific plot, may involve modifying one line in a particular script across all TSAF repositories.

The recent creation of the TSAF package was an important step to provide a single place to organize TSAF code that is shared between analyses. Moving blocks of code from the R scripts into the TSAF package, as encapsulated and documented functions, will be beneficial for the development and maintenance of TSAF analyses.

A thorough research and review of the TSAF analyses is required to identify blocks of code that can be moved to shared functions. The design and development of these functions and maintenance of the TSAF package will be a good investment to efficiently handle a large number of TSAF analyses.

Reference analysis

As the development of TSAF analyses continues, it might be practical to have one reference analysis that demonstrates the latest features and recommended as a template for creating a new TSAF analysis. Currently, the `2021Area37Coastal` analysis serves as the test case for new features and improvements, but a dedicated reference analysis would be beneficial.

Managing output files

A significant challenge in TSAF is that each analysis takes considerable time to run (>1 hr) and produces large output files (>100 MB). Every time a small update is made to the scripts or underlying data, a new run is required and the output

files are likely to change. TSAF development so far has explored two approaches to store the output files.

Approach 1. Initial development (e.g., `area37`) kept the output files outside of the repository. Instead of uploading the output files along with the R scripts, output files were uploaded as GitHub 'release assets'. The advantage of this approach is that the repository remains very light and easy to work with, and takes much less space on the hard drive of a personal laptop.

Approach 2. Later development (e.g., `2021Area37Coastal`) has the output files stored inside the repository. The advantage of this approach is that it reduces the need to manage tags and GitHub releases, and makes it slightly less likely to have mismatching R scripts and output files.

Unfortunately, neither of the above approaches can guarantee a correct match between the R scripts and the output files. In other words, when a change is made to an R script and uploaded to the repository, it's easy to forget or omit running the entire analysis and uploading new output files.

A 3rd approach worth exploring would be not to upload output files to the GitHub repository at all. Instead, the database server would run all analyses locally. Specifically, a GitHub webhook could be developed, so that whenever a change is uploaded to the GitHub repository, the database server pulls the changes, runs the analysis and imports the results into the database. This would guarantee a strong linkage between the TSAF repositories and the database.

Other improvements in TSAF repositories

In upcoming meetings, the TSAF development team will continue to use the TSAF project board (Section 2.3) to discuss, prioritize, and track the above and additional developments related to TSAF repositories.

4.2   Input data warehouse

4.2.1   Current status

The https://github.com/sofia-tsaf/catches repository currently contains the following files with catch data:

```
cap_2021-10-17_193245.csv
cap_all_area37_2021-10-12_64848.csv
cap_flagged_2021-10-12_70055.csv
cap_flagged_area37_2021-10-12_63449.csv
```

The https://github.com/sofia-tsaf/effort repository has been created but is still empty.

4.2.2 Next steps

The data in the `catches` repository data are ready for exploratory use, testing the ability of R scripts to read catch data from the central warehouse instead of a local data directory.

Data can be added to the `effort` repository in CSV format. Alternative structures of the data will be evaluated, before deciding how to organize the effort data from different areas and stocks.

For TSAF analyses of Tier 1 and 3, the data warehouse can incorporate the underlying numerical and categorical data from official stock assessments and expert elicitation. This could further increase the clarity and traceability of the overall SOFIA analysis of stock status.

4.3 R package

4.3.1 Current status

Version 1.0.0 of the TSAF package was released on 10 Dec 2021. The package help page that comes with TSAF lists the following functions, categorized by functionality.

Prepare data:

`addDriors`   add 'driors' (data and priors) column to stocks object
`addEffort`   add effort column to catch data

Calculate:

`calcCat`   stock status categories

Plot:

`plotCat`   summary of stock status categories

The current status of the package is stable and fully documented, passing a strict `R CMD --as-cran` quality check. It will not be submitted to be published on CRAN, however, since it requires the sraplus package that does not fulfill the strict criteria of CRAN packages.

4.3.2 Next steps

The development goal to 'Standardize and shorten scripts' (Section 4.1.2) involves extending the TSAF package. Specific ideas for additional functions have not yet been formulated.

4.4 Database

4.4.1 Current status

The database of TSAF results is implemented in MySQL. Its development is organized in a GitHub repository:

https://github.com/sofia-tsaf/database

Database import and export is managed using Bash shell scripts, which are found in the GitHub repository.

4.4.2 Next steps

Strong link between repositories and database

The link between TSAF repositories and the database of results (Figure 1) is essential for traceability and the fundamental purpose of TSAF. The very basis of the TSAF design is that the results found in the database should match exactly the results produced by the TSAF repositories.

One database script under development loops through the list of repositories and pulls down the `current_status.csv` file to ingest to the database.

The design and development of this linkage is still ongoing. It might be beneficial to maintain a list of TSAF repositories whose results should be imported into the database. Several repositories on https://github.com/sofia-tsaf are not TSAF analyses producing results for the database, e.g., software development repositories, input data warehouse repositories, and exploratory or reference analyses. The database should import results from all relevant TSAF repositories, while omitting other repositories.

Database server managing TSAF output files

One design possibility is to have a dedicated TSAF database server as the main platform to run TSAF analyses and manage output files, in addition to importing the results into the database.

The development goal 'Managing output files' (Section 4.1.2) elaborates on this possible approach, which could involve a GitHub webhook to establish a reliable pipeline of information from TSAF repositories to the database.

5 Acknowledgements

Working with Rishi Sharma and Nicole Tursich on this project is a privilege and joy. Our domains of expertise complement each other, and we share a common vision and enthusiasm to enhance the FAO infrastructure and analytical workflows for estimating the state of the world's fisheries. I would like to acknowledge Colin Millar for our collaboration in creating TAF (Magnusson and Millar 2021), which has served as an inspiration and basis for the TSAF design. Last but not least, I am grateful to Pedro Barros and colleagues at FAO for their guidance and vote of confidence for this technical development project.

6 References

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A   Arni's contributions in 2021

TSAF design

The work on this project is divided been design and development. The design part takes place largely during online technical meetings of the TSAF development team, and is the product of dynamic teamwork and discussions. As the TSAF design borrows both ideas and technical components from TAF (Magnusson and Millar 2021), Arni has served in a lead role in the design of many aspects of TSAF, especially the structure of TSAF repositories, input data warehouse, and the R package.

TSAF repository development

On the development front, Arni started by creating the `area37` repository, demonstrating how a TSAF analysis can be efficiently divided into four scripts (`data.R`, `model.R`, `output.R`, and `report.R`) and taking advantage of the existing TAF package to support reproducibility. He then made incremental improvements to the `area37` analysis, giving objects and files short and generic names that can be used consistently between different SOFIA analyses. The `area37` repository served as a template for all later TSAF repositories.

Teaching and documenting

Since the other development team members were rather new to using GitHub repositories and TAF workflows, Arni has dedicated project time to teaching and documenting how those technologies are used in TSAF. He also analyzed the extent of package dependencies of the sraplus package, which is especially relevant for the reproducibility aspect of TSAF analyses.

Stock-specific analysis

Later development focus of Arni's work was the generalization of TSAF analyses, to allow effort data and priors to be either stock-specific or shared across stocks. This improvement was first implemented as a general structure for the input data files and a revised block of code in the `data.R` script of analysis `2021Area37Coastal`. To select which analytical option to use, a flag `stocks.combined` in the data script is set to `TRUE` or `FALSE`, with corresponding if-constructs added to the code. These if-constructs were later replaced with a cleaner solution, as encapsulated functions in a new dedicated TSAF package.

R package

The new functionality of stock-specific analysis led Arni to develop a new R package called TSAF that is now operational. Acting as a single place of analytical methods used in all TSAF analyses, the greatly improves the ability to manage and maintain the large number of TSAF analyses behind SOFIA.

Contributions to project management

Arni proposed and created the project board used to track TSAF development progress, along with a discussion board, milestones, and issue tracker. Finally, he wrote the current report, which consolidates the progress made so far, conveys a design manifesto, documents existing features, and serves as a foundation for the next steps and team discussions on TSAF development.

Links to deliverables

- [area37](#) analysis
- [sraplus](#) list of dependencies
- [Project board](#)
- [2021Area37Coastal](#) analysis
- [TSAF](#) package
- [This](#) current report