1. Let's consider using PRIMER

- 1.1 PRIMER has a lot going for it
- 1.2 PRIMER has some down sides
- 1.3 Pros and Cons of using PRIMER

1.1 PRIMER has a lot going for it

PRIMER has a special focus - robust multivariate methods

PRIMER is a specialised piece of software that is purposefully designed to analyse multivariate data. It is especially good at handling high-dimensional, non-normal data, which are not able to be analysed using classical multivariate statistical methods.

Non-normal high-dimensional data arise commonly in community ecology and environmental science, where abundances (counts, biomass, presence/absence or cover values) of individual species are sampled. They also arise in a lot of other contexts.

Many of the routines in PRIMER implement statistical or graphical methods that rely flexibly on a **similarity** (or dissimilarity or distance) matrix among sample units (or variables), or their ranks, as a fundamental foundation. The statistical methods and tests in PRIMER are very robust. They use carefully constructed permutation algorithms to ensure all tests are valid and distribution-free. The initial suite of **non-parametric methods** in the PRIMER base package (e.g., ANOSIM, RELATE, BEST, MDS, SIMPROF, LINKTREE, TAXDTEST, etc.) are further extended by a suite of **semi-parametric methods** offered in the PERMANOVA+ add-on package for PRIMER (e.g., PERMANOVA, PERMDISP, dbRDA, DISTLM, CAP, etc.), enhancing the overall capability of PRIMER software.

PRIMER (and PERMANOVA+) arose in response to (mostly marine) scientists, to service a clear need to analyse ecological community data. However, the methods are sufficiently general, robust and flexible to accommodate multivariate data in virtually any applied setting (e.g., genetics, economics, psychology, medicine, agriculture, etc.). This has led to the broad use and popularity of PRIMER/PERMANOVA+ software globally as a useful general tool for performing robust multivariate analysis.

PRIMER is extremely easy to use

PRIMER is very easy to use (point and click). It operates in a Windows GUI that is familiar, straightforward and intuitive. You don’t have to program anything or write any code. You never have to worry about de-bugging the engines underneath the user interface. Data types are explicit and clear, on input.

In addition, PRIMER offers some tailored error messaging that can assist you to make sensible decisions along your statistical analysis pathway, given the type of data you are working with. Of course, you have full control and can bypass suggestions or defaults offered by the package, but those who are new to PRIMER (and those of us who are old hands!) are helpfully supported by these features.

PRIMER also has some tailored 'Wizards' to make data import and other multi-task analysis pipelines quicker and easier to achieve. This leaves you more time to concentrate on the results and your interpretation, instead of struggling with code.

Ease-of-use also makes it super quick to trial a host of different approaches on a single (or multiple) sets of data, without losing track of your core purpose. Everything is kept within a single file (a PRIMER workspace, *.pwk), and you can even add your own notes *in situ*. This can help you keep track of your rationale for choosing different analyses or pathways, and is also useful for recording your interpretations of results.

PRIMER was designed by a small team of experts

PRIMER (and PERMANOVA+) were designed and created by a small team of academically acclaimed experts in the fields of statistics, ecology, marine science and environmental science, who teamed up with experts in physics, math and software engineering. The academics responsible for PRIMER (and PERMANOVA+) invented the majority of the multivariate methods that this software implements. The PRIMER team are (and have always been) wholly dedicated to providing user-friendly software that implements the statistical methodologies that they have themselves developed, along with some additional well-researched tools that readily complement these techniques, to yield a holistic and consistent package.

You can trust results obtained using PRIMER

Results obtained using PRIMER are reliable. PRIMER's small dedicated team is uncompromising when it comes to quality. The programs and routines are backed by academic excellence and reliability. This ensures not only the validity of the results obtained using PRIMER, but also ensures the commercial viability of PRIMER products and the PRIMER-e enterprise. If you pay for something (and PRIMER is not free), it has to work. The program, including inter-dependencies among routines, are thoroughly tested before the release of any upgrades or updates. The internal workings of the PRIMER software are coherent and consistent.

Although no package can truly claim that it has absolutely no bugs, the team at PRIMER-e is dedicated to fixing any bugs you might find. *(Note: If you find a bug (or even a suspected bug) in PRIMER or PERMANOVA+ software, please write to us directly: primer@primer-e.com. We think it is absolutely great to discover bugs, so they can be fixed!)*

All of the methods and routines available in PRIMER and PERMANOVA+ are also backed up by:

- accessible descriptions of core methods published in the **primary literature**,
- thorough and freely-available documentation in the form of a suite of **software manuals**, and
- frequent international **courses** held online and/or in-person globally.

PRIMER does what no other software will do

A large number of the methods and routines available in PRIMER (and PERMANOVA+) are found nowhere else. There are too many methods unique to PRIMER to name and describe here, but a short list of some of my favorites would include:

- up to three-way ANOSIM, with ordered or un-ordered factors

- metric and threshold-metric MDS
- ordination of bootstrap averages with confidence regions
- kRCLUSTER analysis with SIMPROF tests
- taxonomic distinctness biodiversity measures
- PERMDISP for analysing beta diversity
- PERMANOVA that correctly handles any design, including random factors, nested factors, covariates, unbalanced cases, *a priori* contrasts, etc.
- Pairwise comparisons accommodating the full model, including interactions
- CAP for gradients or groups, including estimates of leave-one-out allocation success and placement of new samples onto CAP axes
- Shade plots with coherent species (or other) groupings
- Segmented bubble plots
- Distances among centroids in a chosen resemblance space and so much more...

PRIMER is definitely not designed to do everything, but what it is designed to do, it does extremely well. You can bank on it.

1.2 PRIMER has some down sides

Like any software package, PRIMER has some down sides.

PRIMER has a pretty specific niche

As already mentioned, PRIMER's focus is on non-parametric and semi-parametric techniques and graphics for analysing multivariate data, particularly ecological data. It doesn't offer much in terms of standard classical statistical methods, graphics and modeling. In truth, there are a host of other software packages out there that already do that sort of thing (SAS, JMP, SPSS, Stata, Matlab, R, etc.), and PRIMER has never aimed to compete with any of those.

This means that PRIMER (typically) cannot (currently) serve as your *only* software tool for data analysis. It is admittedly rather a pain to have to (potentially) swap between different software tools to accomplish all of your desired stats for a given project. The PRIMER-e team is always seeking to develop PRIMER for the future, not only within its niche, but also to progressively embrace an array of existing statistical methods (classical or otherwise) that are useful, particularly for ecology. *(Note: If you have ideas about this that you'd like to share, particular things you really wish were in PRIMER, then please contact the team at PRIMER-e directly: primer@primer-e.com.)*

PRIMER is not free

The PRIMER-e team is small and consists of very dedicated individuals. We have to support ourselves and our families, so the PRIMER (and PERMANOVA+) software is not free.

PRIMER is not platform-independent

PRIMER runs on a Windows operating system. It cannot (yet) be run natively on Linux or Mac OSX, but it can be run *via* virtualization software.

PRIMER doesn't (currently) have scripting

When you use PRIMER, you do not have to mess with any code. The clear down side to this is that there is no way to modify PRIMER to do extra things (or different things or multiple things) beyond what it currently does, but that you might really wish it would do for you.

This also means that you cannot (currently) create a 'script' inside PRIMER. Perhaps you want to run a particular PERMANOVA design a thousand times (e.g., on simulated datasets), or maybe you want to implement the same series of steps in a *bespoke* analysis pathway routinely (e.g., every year when your monitoring data comes in) or on multiple datasets. It would be really nice to have some sort of scripting tool within PRIMER that would allow things like this. (Watch this space!)

1.3 Pros and Cons of using PRIMER

To re-cap and summarise, below is a table outlining the primary pros and cons of using PRIMER, as I see it:

Pros	Cons
$\bullet$ Easy to use	$\bullet$ Not free
$\bullet$ High-quality results you can trust	$\bullet$ Not platform-independent (Windows only)
$\bullet$ Special focus: robust multivariate methods, especially for ecology	$\bullet$ Niche is somewhat narrow
$\bullet$ Built by a small team of experts	$\bullet$ Not much univariate or classical stats
$\bullet$ Does not require programming skills or code-writing	$\bullet$ No scripting (yet)
$\bullet$ Does many things that no other software will do	
$\bullet$ Handles complex experimental/sampling designs correctly	
$\bullet$ Great for scientists/practitioners	