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Construction of individuals ddRADseq libraries for macro-algae (Kelp) V.3 V.3

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Stéphane Mauger , Aurélien Baud , Gildas Le Corguillé , Gwenn Tanguy , Erwan Legeay , Emeline Creis , Myriam Valero , Philippe Potin , Christophe Destombe (2023).Genetic resources of macroalgae: Development of an efficient method using microsatellite markers in non-model organisms. *Algal Research - Biomass, Biofuels and Bioproducts*, 2023, 75, pp.103251. ([10.1016/j.algal.2023.103251](https://doi.org/10.1016/j.algal.2023.103251))

Reynes L., Fouqueau L., Aurelle D., Mauger S., Destombe C., Valero M. (2023). Temporal genomics help in deciphering neutral and adaptive patterns in the contemporary evolution of kelp populations. JEB. <https://doi.org/10.1101/2023.05.22.541724> <https://mycore.core-cloud.net/index.php/s/JzWr1GDe3B1Gpzk><https://hal.science/hal-04287077>

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Protocol status: Working

We use this protocol and it's working

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Abstract

This protocol describes a double digested restriction-site associated DNA (ddRADseq) procedure, that is a variation on the original RAD sequencing method ([Davey & Blaxter 2011](#)), which is used for *de novo* SNP discovery and genotyping.

This protocol differs from the original ddRADseq protocol ([Peterson et al 2012](#)), in which the samples are pooled just after the ligation to adaptors (i.e. before size selection and PCR). This protocol is an update of the protocol from [Claire Daguin Thiebaut et al. \(dx.doi.org/10.17504/protocols.io.bv4tn8wn\)](#) adapted for macro-algae.

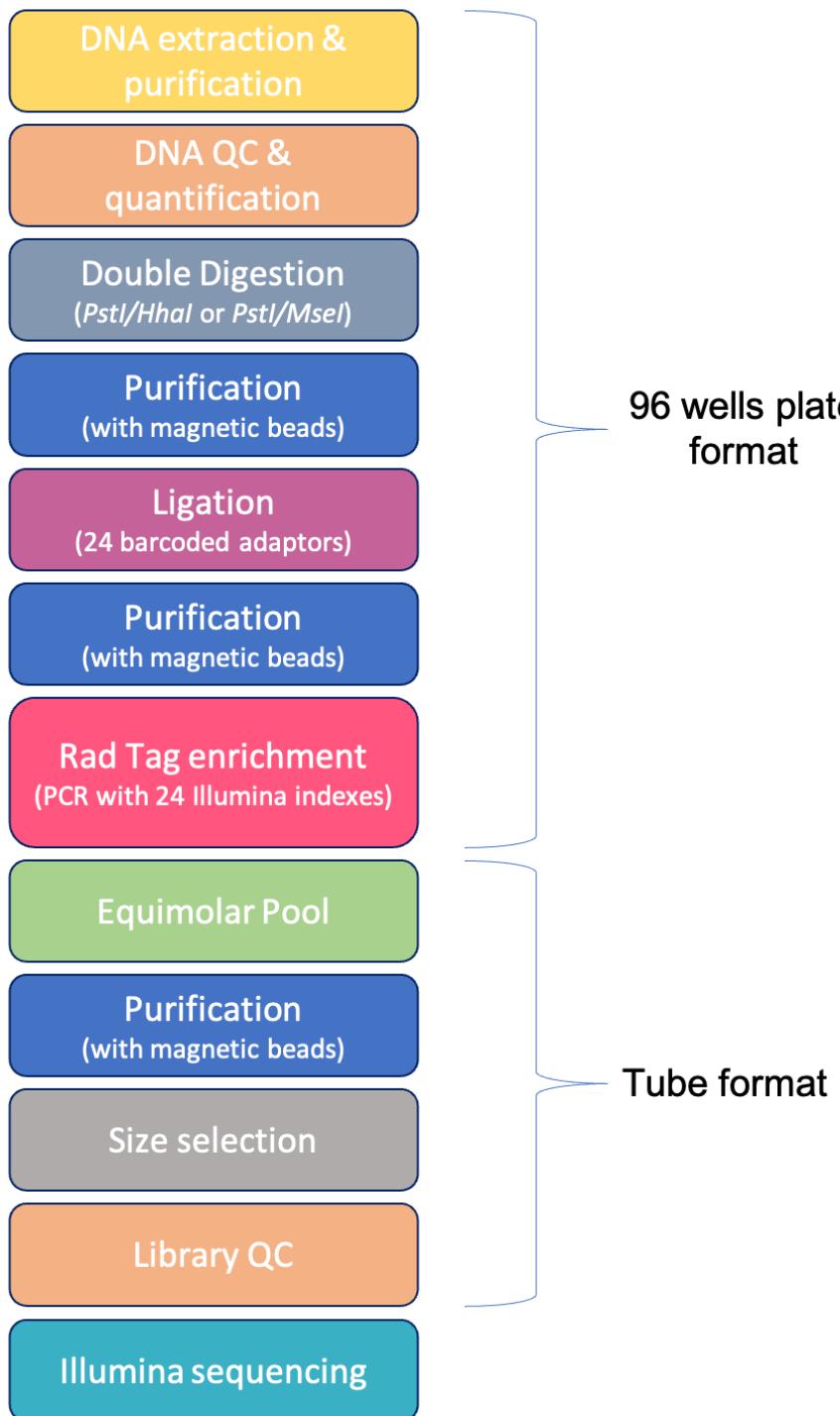
The following protocol is intended for the construction of individual ddRADseq libraries from genomic DNA of various macro-algae samples (Kelp). In the present protocol, we added a genomic DNA purification step to eliminate the inhibitors of PCR and Ligation present in macro-algae (polysaccharides). Moreover, all samples are treated separately until final PCR amplification (Rad Taq enrichment step) performed before pooling.

Despite being slightly more costly and time-consuming in the lab, it allows for fine adjustment of each sample representation in the final library pool ensuring similar number of reads between samples. Finally, we have defined new P1 adapters (barcodes) with variable sequences and variable sizes (6bp to 13bp) to increase the efficiency of the Illumina sequencing.

Briefly, purified genomic DNA from the samples are individually digested with 2 restriction enzymes **PstI/HhaI** or **PstI/MseI** (one rare-cutter and one more frequent cutter) then ligated to a barcoded adaptor (among 24 available) at one side, and a single adaptor at the other side, purified with magnetic beads, and PCR-amplified allowing the addition of a Illumina index (among 24 available) for **multiplexing a maximum of 576 samples per library**. Samples are then pooled in equimolar conditions after visualisation on an agarose gel. Purification and size selection is then performed before final quality control of the library and sequencing.

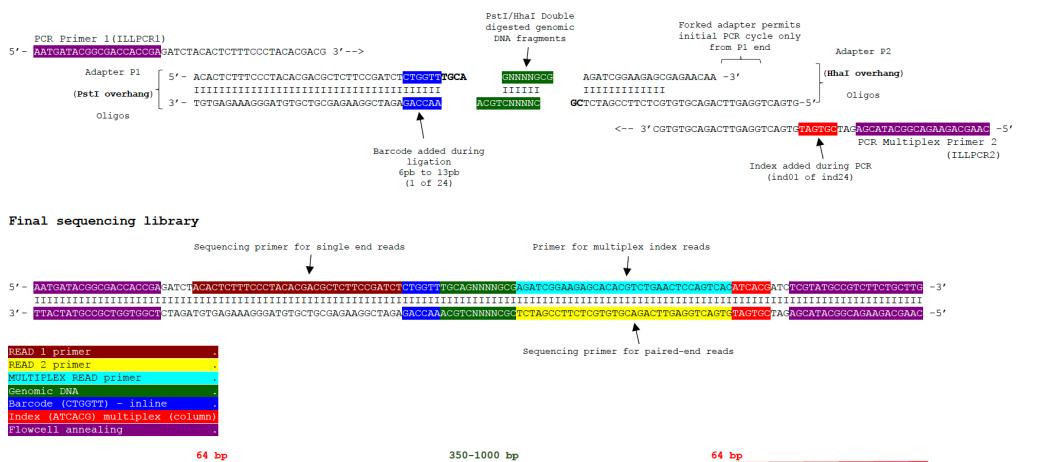
This protocol has proven its effectiveness in several genetic studies of macro-algae populations.

Double-digested restriction site associated DNA sequencing (ddRADseq) overview



Overview of ddRADseq libraries preparation

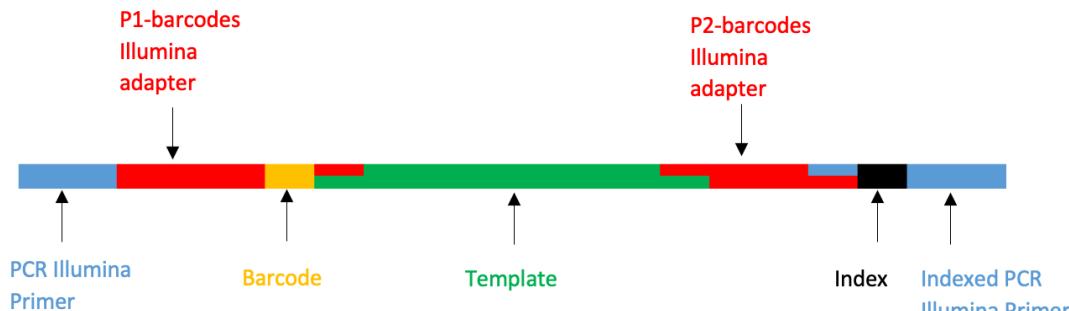
Diagram of Oligos, Adapters, Digested genomic DNA



BRIEF GLOSSARY

Adapter: fully or partially double-stranded product of annealing two oligos. Adapters are ligated to genomic DNA at restriction enzyme cut sites in order to add barcodes and common PCR priming sequences.
Barcode: short DNA sequence downstream of the sequencing primer annealing region of an adapter. Used to resolve products of different ligation reactions (usually separate individuals) after sequencing pooled libraries.
Fragment: section of genomic DNA resulting from restriction enzyme cleavage.
Index: short DNA sequence introduced during PCR amplification of the final library that uniquely identifies products of that PCR reaction. Used combinatorically with Adapter P1 barcodes to resolve multiplexed sample pools.
Library: a collection of sequencing-competent fragments

Diagram of oligos and adaptaters; final library; BRIEF GLOSSARY



Final ddRAD library construction

Protocol materials

-  **PstI-HF New England Biolabs Catalog #RS3140RS** Step 11.1
-  **Hhal - 10,000 units New England Biolabs Catalog #R0139L** Step 11.1
-  **CutSmart® Buffer New England Biolabs Catalog #B7204S** Step 11.1
-  **Sodium Chloride Fisher Scientific Catalog #S271** Step 1
-  **EDTA 0.5M Fisher Scientific Catalog #MRGF-1202** Step 2
-  **Ethanol, Absolute, Molecular Biology Grade Thermo Fisher Scientific Catalog #BP2818500** In 3 steps
-  **Msel - 500 units New England Biolabs Catalog #R0525S** Step 11.1
-  **Quant-iT™ PicoGreen™ dsDNA Assay Kit Invitrogen - Thermo Fisher Catalog #P11496** Step 9.1
-  **Q5 Hot Start High-Fidelity DNA Polymerase - 500 units New England Biolabs Catalog #M0493L** Step 31
-  **Tris-HCl 1M solution pH 8.0 Molecular Biology Grade Ultrapure Thermo Scientific Catalog # J22638.AP** Step 2

Before start

1. Prepare all buffers and solutions in advance (see Step 1 to Step 5)
2. If not using Retsch © Mixer Mill MM 301 (or equivalente) and Grinding ball for the sample grinding, you can use Lysing Matrix H tube with FastPrep-24™ Classic or manual grinding as a last resort.

Solutions and buffers preparations

15m

1 5 M sodium chloride solution (NaCl)

5m

29.2 g NaCl (M.W. 58,44)

Dissolve the salt in MilliQ water and fill up to 100 mL.

Autoclave.

Store at Room temperature

 Sodium Chloride Fisher Scientific Catalog #S271

2 Annealing buffer stock (10x)

10m

Annealing buffer composed 100 mM Tris-HCl, pH8; 500 mM NaCl and 10 mM EDTA

5 mL Tris-HCl, 1M solution, pH 8,0

5 mL NaCl, 5M solution

1 mL EDTA, 0.5 M solution

39 mL MilliQ water

Homogenize and autoclave.

Store at Room temperature

 Tris-HCl 1M solution pH 8.0 Molecular Biology Grade Ultrapure Thermo Scientific Catalog # J22638.AP

 EDTA 0.5M Fisher Scientific Catalog #MRGF-1202

Preparation of double-stranded barcoded P1 adaptors 4 μ M

1h 10m

- 3 Single-stranded oligos NGS grade P1 need to be annealed with their appropriate partner before ligation. We provide sequences for 48 uniquely barcoded adapter P1 oligo pairs (oligos P1_PstI_x.F and P1_PstI_x.R), **see the Barcoded_P1_adaptors.xlsx file below**. To create Adapter P1, combine each oligo Forward with its complementary oligo Reverse in a 1:1 ratio in working strength annealing buffer (final buffer concentration 1x) for a total annealed adapter concentration of 4 μ M.

In house barcoded P1 adaptors sequences (NGS grade needed) :

 Barcoded_P1_adaptors.xlsx 13KB

- 3.1 In a PCR plate wells, combine each oligo P1_PstI_x.F with its complementary oligo P1_PstI_x.R :

 4 µL oligo Forward (100µM)

 4 µL oligo Reverse (100µM)

 10 µL Annealing buffer (10x)

 82 µL nuclease free water

30m

- 3.2

A	B	C	D	E	F	G	H
P1_PstI_01			P1_PstI_09			P1_PstI_17	
P1_PstI_02			P1_PstI_10			P1_PstI_18	
P1_PstI_03			P1_PstI_11			P1_PstI_19	
P1_PstI_04			P1_PstI_12			P1_PstI_20	
P1_PstI_05			P1_PstI_13			P1_PstI_21	
P1_PstI_06			P1_PstI_14			P1_PstI_22	
P1_PstI_07			P1_PstI_15			P1_PstI_23	
P1_PstI_08			P1_PstI_16			P1_PstI_24	

Example of a plate map for barcoded P1 adaptors. Allow enough space between the rows to avoid cross-contaminations between barcodes.

- 3.3 The reaction is performed in a thermocycler with the following PCR cycling conditions :

40m

A	B	C	D
Cycle step	Temperature	Time	Cycles
Initial Denaturation	97.5°C	2.5 min	1
Annealing	96°C (-3°C per cycle)	1 min	25
Hold	4°C		

PCR cycling conditions

Store at  4 °C (or at  -20 °C for a long-term storage)

Preparation of double-stranded P2 adaptors 40µM

45m

- 4 Single-stranded oligos NGS grade P2 need to be annealed with their appropriate partner before PCR. We provide sequences for 4 uniquely adapter P2 oligo pairs (oligos P2_Hhal.F and P2_Hhal.R or P2_Msel.F and P2_Msel.R), **see the No-Barcoded_P2_adaptors.xlsx file below.** To create Adapter P2, combine each oligo Forward with its complementary oligo Reverse in a 1:1 ratio in working strength annealing buffer (final buffer concentration 1x) for a total annealed adapter concentration of 40µM.

No-barcoded P2 adaptors sequences (NGS grade needed) :



No-Barcoded_P2_adaptors.xlsx 10KB

- 4.1 In 1.5mL microtube, combine oligo P2_Hhal.F with its complementary oligo P2_Hhal.F (or P2_Msel.F and P2_Msel.R)

5m

 400 µL oligo Forward (100µM)

 400 µL oligo Reverse (100µM)

 100 µL Annealing buffer (10x)

 100 µL nuclease free water and mix by pipetting

Then aliquot this volume into  125 µL in each well of a 8- PCR tube strip.

- 4.2 The reaction is performed in a thermocycler with the following PCR cycling conditions :

40m

A	B	C	D
Cycle step	Temperature	Time	Cycles
Initial Denaturation	97.5°C	2.5 min	1
Annealing	96°C (-3°C per cycle)	1 min	25
Hold	4°C		

PCR cycling conditions

Pool all reaction in a  1.5 mL tube.

Store at  4 °C (or at  -20 °C for a long-term storage).

Preparation of Illumina indexed primers mix (5µM)

30m

- 5 In 24  1.5 mL microtubes, combine each of the 24 Illumina indexed reverse primers ILLPCR2_ind01 to ILLPCR2_ind27 (no primer numbers ind17, ind24 and ind26) with the Illumina no-indexed forward primer ILLPRC1, **see the Illumina_indexed_primers.xlsx file below.**

30m

 5 µL ILLPCR1 oligo forward (100µM)

 5 µL ILLPCR2 oligo reverse (100µM) ind01 to ind27 (one per tube)

 90 µL nuclease free water and mix by pipetting

Store at  4 °C (or at  -20 °C for a long-term storage)

Illumina indexed primers sequences (NGS grade needed) :



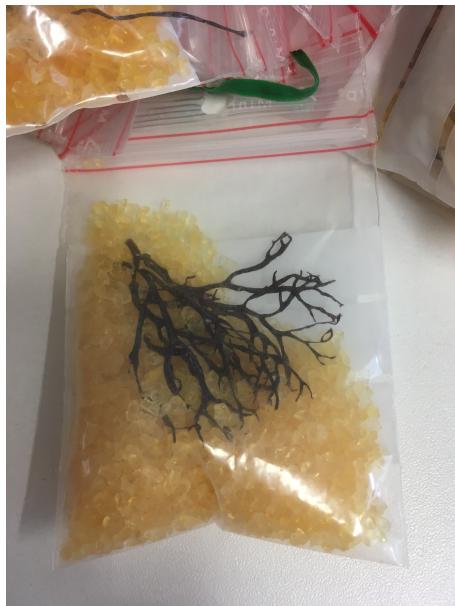
Illumina_indexed_primers.xlsx 10KB

Genomic DNA extraction and purification

7h 47m

6 Genomic DNA extraction

Upon collection, a piece of tissue was cut out from a spot that was free of algal and animal epiphytes and stored in silica gel. Total genomic DNA was extracted from 15 to 20 mg of grinded dry tissue using the Nucleospin 96 plant kit (Macherey-Nagel, Germany).



Example of micro-algae stored in silica gel

 Silica gel drying agent, with moisture indicator (orange gel) **VWR**
International Catalog #1.03806.0001

- 6.1 In a Rack of Tube Strips (consumable of NucleoSpin 96 Plant II kit) add  15 mg to  20 mg of dry tissue of each sample with one 3 mm grinding ball stainless steel. Close the Tubes Strips with Cap Strips.



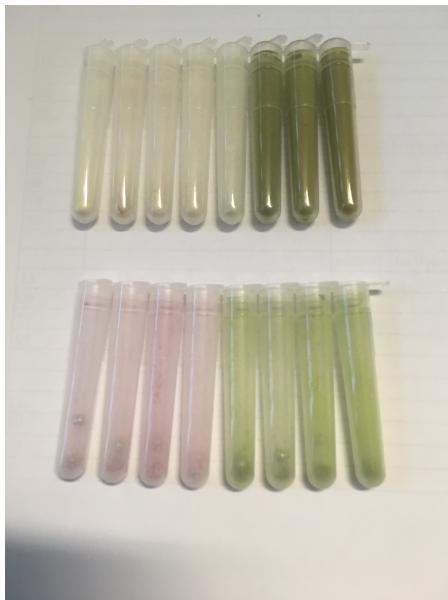
Example of dry algae with 3 mm steel ball before and after grinding process in individual tube

3h

 Grinding ball stainless steel **VWR International Catalog #412-0254**

- 6.2 Grind dry tissues using Mixer Mill MM400 Retsch using 2 cycles of  00:02:00 at maximum frequency.

5m



Example of grinded samples in 96 wells plate format

 MIXER MILL MM 400 **Retsch**

- 6.3 The extraction was performed according to the manufacturer's instructions using the PL1 lysis buffer except that we added one wash step with PW1 buffer (2 times PW1 washes in total) and one wash step with PW2 buffer (3 times PW2 washes in total). The extracted DNA was eluted into 120 µL (2 x 60 µL) of the supplied elution buffer.

2h

 Instruction-NucleoSpin-96-Plant-II.pdf 912KB

Store at  4 °C (or at  -20 °C for a long-term storage)

 NucleoSpin 96 Plant II, 96-well kit for DNA from plants **Macherey-Nagel Catalog #740663.4**

3h 45m

7 Genomic DNA purification

The genomic DNA extracts were purified using the NucleoSpin gDNA Clean-up XS, Micro kit for DNA clean up and concentration (Macherey-Nagel, Germany).

The purifications were performed according to the manufacturer's instructions with elution into 30 µL (2 x 15 µL) of the supplied elution buffer.

- 7.1 Transferring the  120 µL of each samples  into 1.5 mL microtubes. Add nuclease free water to fill up to  400 µL . 1h

- 7.2 The purifications were performed according to the manufacturer's instructions with elution into 30 µL (2 x 15 µL) of the supplied elution buffer. 2h



Instruction-NucleoSpin-gDNA-Clean-... 805KB

- 7.3 Removal of residual ethanol and concentration were performed by incubation  00:15:00 at  70 °C 15m

- 7.4 The purified gDNA of each sample was transferred in a 96 wells PCR plate. 30m

Store at  4 °C (or at  -20 °C for a long-term storage)

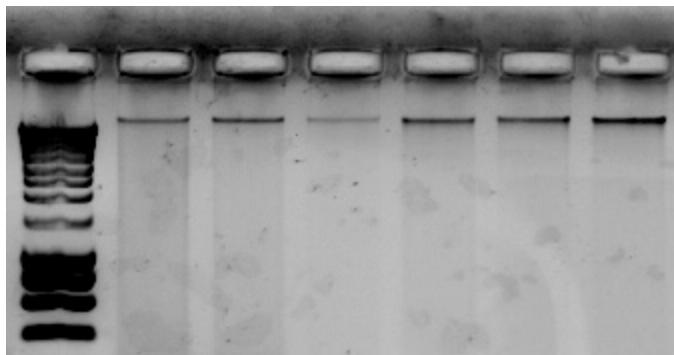


NucleoSpin gDNA Clean-up XS, Micro kit for DNA clean up and concentration **Macherey-Nagel Catalog #740904.250**

Genomic DNA Quality and Quantification 4h

8 Quality Control of Genomic DNA 2h

Optional: load  1 µL to  3 µL of the Genomic DNA extract on an agarose gel to evaluate its quantity and quality using electrophoresis.



Example of agarose gel picture of genomic DNA

9 Quantification of Genomic DNA (Preparation for one 96 wells PCR plate) using PicoGreen™

Quantify Genomic DNA extract using PicoGreen™.

2h

Protocol

NAME



Qant-iT™ PicoGreen® dsDNA Quantification

CREATED BY

Roey Angel

PREVIEW

- 9.1 Take out all reagents from the fridge and bring them to room temperature.
Take out the DNA samples from the freezer. DNA samples should be slowly thawed on ice

Note

Quant-iT™ PicoGreen® dsDNA reagent is dissolved in dimethylsulfoxide (DMSO), which freezes below 19 °C. The reagent must be completely thawed before using it by bringing it to room temperature. After the reagent thawed, it is advisable to briefly vortex the tube to make sure it is adequately mixed and to spin it down in a centrifuge or a mini centrifuge.

Note

Quant-iT™ PicoGreen® dsDNA reagent is light sensitive and should be protected from light at all times.



Quant-iT™ PicoGreen™ dsDNA Assay Kit **Invitrogen - Thermo Fisher Catalog #P11496**



Greiner Bio-One 96-well sterile polystyrene plate, high binding, colour plate & bottom: black **Dutscher Catalog #655077**

9.2 Preparation of 11 mL of 1X TE buffer

In  15 mL sterile and nuclease-free tube

 550 µL 20X TE (included in the kit)

 10.450 mL nuclease-free water

Mix by inverting the tube several times.

9.3 Preparation of DNA solution at 5000 pg/µl (for 3 ranges)

In  0.5 mL nuclease-free tube

 4 µL DNA-standard stock solution (λ DNA 100 ng/µl)

 76 µL 1X TE buffer

Mix by inverting the tube several times.

9.4 Preparation of the standard range 0 pg/µl to 1000 pg/µl

Prepare the following standard mixture in 8  0.5 mL nuclease-free tubes

A	B	C	D	E
Tubes	Standard DNA solution concentration (pg/µL)	Standard DNA solution volume (µL)	1X TE (µL)	Final DNA concentration (pg/µL)
1	5000	42	168	1000
2	5000	21	189	500
3	5000	9	171	250
4	1000	21	189	100
5	500	21	189	50
6	100	18	162	10
7	50	18	162	5
8	0	0	180	0

Standard DNA solutions preparation

Pipette  50 µL of each standard mixture in the first two columns of the black, sterile, 96-well plate :

A	B	C	D	E	F	G	H
1000 pg/µL	1000 pg/µL	unknown DNA					
500 pg/µL	500 pg/µL	unknown DNA					
250 pg/µL	250 pg/µL	unknown	unknown	unknown	unknown	unknown	unknown

A	B	C	D	E	F	G	H
		DNA	DNA	DNA	DNA	DNA	DNA
100 pg/µL	100 pg/µL	unknown DNA					
50 pg/µL	50 pg/µL	unknown DNA					
10 pg/µL	10 pg/µL	unknown DNA					
5 pg/µL	5 pg/µL	unknown DNA					
0 pg/µL	0 pg/µL	unknown DNA					

Exemple of map plate for PicoGreen™ quantification

- 9.5 Pipette 49 µl of 1X TE buffer in the remaining wells.

 49 µL 1X TE buffer

- 9.6 Pipette 1 µl of the unknown DNA samples in the remaining wells.

 1 µL of DNA sample

9.7 Prepare PicoGreen® work solution

In  10 mL nuclease-free tube

 25 µL picogreen® 200X solution (included in the kit)

 4.975 mL 1X TE buffer

Mix and protect from light.

- 9.8 Pipette  50 µL of PicoGreen work solution in each well, including the standard and unknown sample wells.

- 9.9 Protect the 96-well plate from light and incubate for  00:05:00 at room temperature.

5m

- 9.10 Place the plate in a plate reader and measure the fluorescence according to the following parameters:

Excitation ~480 nm

Emission ~520 nm

Integration time 40 s

Lag time	0 s
Gain	Optimal
Number of flashes	10
Calculated well	highest standard
Shaking	5 s

Equipment

Synergy 2

absorbance microplate reader	NAME
BioTek	TYPE
Synergy2	BRAND
https://www.bioteck.com/products/detection/	SKU
	LINK

Equipment

SPARK

Microwell plate reader	NAME
TECAN	TYPE
SPARK	BRAND
https://www.tecan.com/blog/spark-multimode-microplate-reader-for-high-performance-cell-based-fluorescence-assays	SKU
	LINK

- 9.11 Plot the measured fluorescent values of the standard samples against their known concentrations and fit a linear curve using linear regression. Make sure that the coefficient of determination (R^2) is close to 1 (typically > 0.99). Calculate the DNA concentrations in the

unknown samples using the slope and intercept parameters of the linear equation. Output values you obtained are in pg/ μ L, assuming 1 μ L of each sample was used.

Genomic DNA preparation

1h

- 10 In a PCR plate, put around 100 ng of genomic DNA in a volume of $\text{40 }\mu\text{L}$ (in nuclease free water or Tris-HCl 5mM pH 8.5) for each sample. If possible, randomize the location of samples in the microplate. Keep a few empty wells for negative controls.

Double digestion

20h

- 11 Double digest around 100 ng of high quality genomic DNA with selected restriction enzymes $\text{50 }\mu\text{L}$ reaction volume. Use a digestion buffer appropriate for both enzymes. Here, we will do the protocol for the **PstI** and **Hhal** couple of enzymes but it's same with **PstI** and **MseI** couple. Both couple of enzyme works well for micro-algae but it's possible to test double digestion on few sample to select the best couple of enzymes. The best couple given large smear with size range 100 bp to 1000 pb.

- 11.1 Vortex all reagents, except enzymes (stored at $\text{-20 }^\circ\text{C}$), for approximately $00:00:05$.
 Spin down all reagents for approximately $00:00:05$ and place On ice .
 In a microtube, prepare the digestion mix, according to the following table for a total volume of $\text{50 }\mu\text{L}$:

10s

A	B	C	D	E
	Initial concentration	Final concentration	n=1	n=100 (1 plate)
Genomic DNA		$\sim 100 \text{ ng}$	$40 \mu\text{L}$	
Cutsmart buffer	10X	1X	$5 \mu\text{L}$	$500 \mu\text{L}$
Enzyme 1 (PstI HF)	$20 \text{ u}/\mu\text{L}$	10U	$0.5 \mu\text{L}$	$50 \mu\text{L}$
Enzyme 2 (Hhal or MseI)	$20 \text{ u}/\mu\text{L}$	10U	$0.5 \mu\text{L}$	$50 \mu\text{L}$
nuclease-free water			$4 \mu\text{L}$	$400 \mu\text{L}$
TOTAL			$50 \mu\text{L}$	$1000 \mu\text{L}$

Digestion master mix composition

 PstI-HF New England Biolabs Catalog #RS3140RS

 Hhal - 10,000 units New England Biolabs Catalog #R0139L

 MseI - 500 units New England Biolabs Catalog #R0525S

 CutSmart® Buffer New England Biolabs Catalog #B7204S

11.2 Vortex the master mix and spin down.

5s

Aliquot  125 µL of the digestion master mix in each well of a 8-PCR tube strip.

In the DNA plate (containing  40 µL per well), add  10 µL of digestion master mix with a x8 multichannel pipette and mix by pipetting, seal PCR plate and spin down.

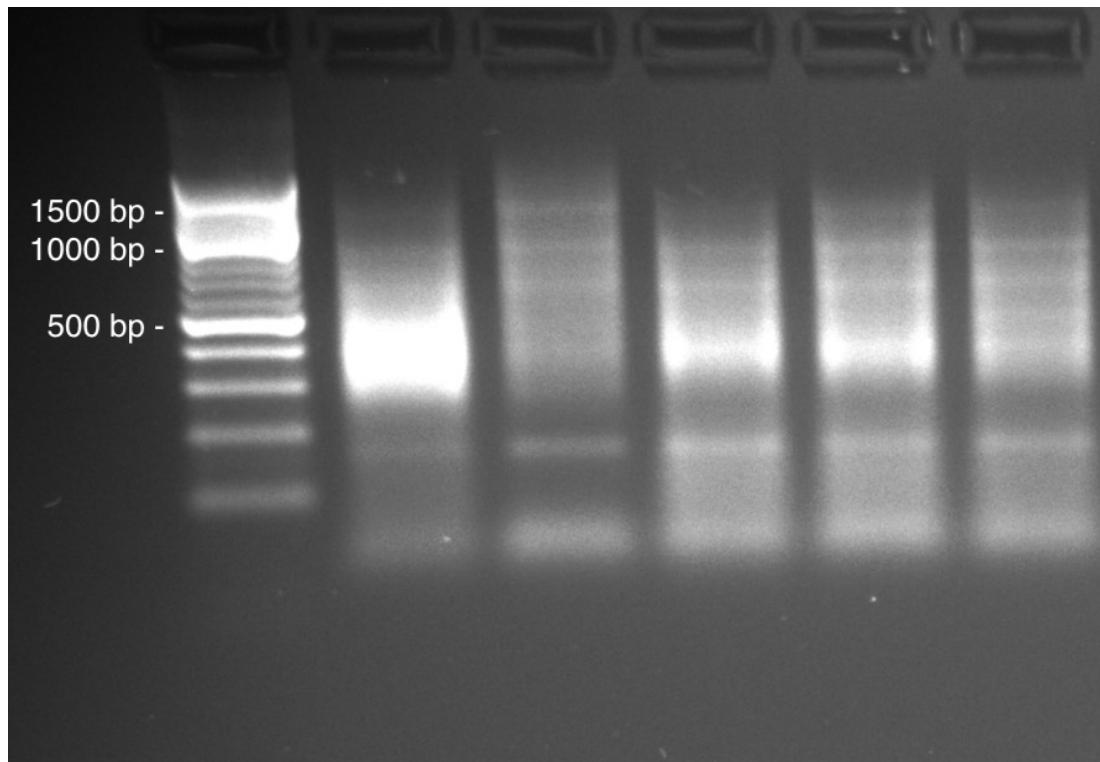
Incubate at  37 °C  Overnight

Then store at  4 °C

Check digestion on an agarose gel

2h

12 Check the efficiency of the digestion by electrophoresis of  5 µL of digested DNA in a 1.5 % agarose gel (standard quality). High molecular weigh DNA should no longer be visible.



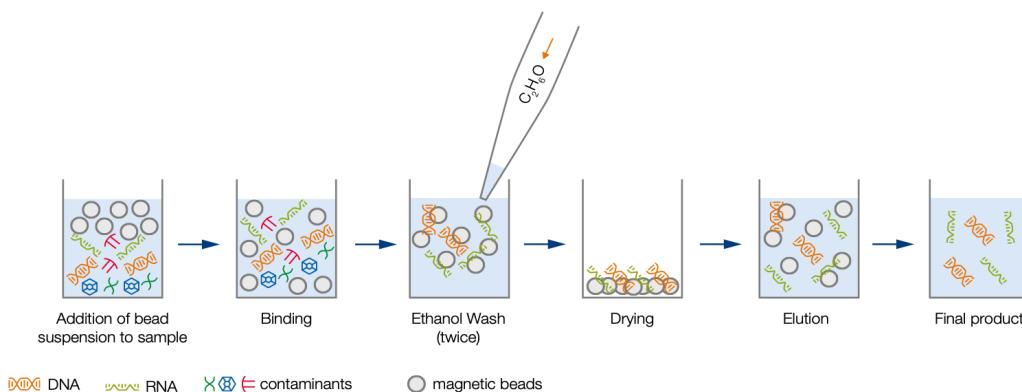
Example of agarose gel picture after digestion of genomic DNA. Size marker is a 100bp ladder.

Bead purification (96-well plate format)

1h

- 13 This protocol can be used to remove contaminants, unligated adapters, enzymes, buffer additives, salts... and short DNA fragments. The method utilizes a single-size selection step : After adding the appropriate volume of Bead Suspension to the DNA sample, beads will bind larger fragments. The supernatant contains smaller fragments and contaminants that are discarded. For most NGS sequencing applications it is optimal to remove all fragments below 100 bp. This can be achieved by using a volume ratio (bead suspension to sample) of 1:1, which is described in the following protocol.

Schematic Workflow Overview



NucleoMag kit for clean up and size selection Workflow (Macherey-Nagel)



NucleoMag kit for clean up and size selection of NGS library prep reactions **Macherey-Nagel Catalog #744970.50**

14 **Before starting**

Prepare  50 mL of fresh 80% Molecular Biology Grade Ethanol

 40 mL Molecular Biology Grade Ethanol

 10 mL nuclease-free water



Ethanol, Absolute, Molecular Biology Grade **Thermo Fisher Scientific Catalog #BP2818500**

Remove the NucleoMag® NGS Bead Suspension from the fridge. Let for approximately 30 min to bring the bead suspension to  Room temperature .

Then, vortex this Bead Suspension stock solution carefully until homogenized and put in a reagent reservoir.

15 Binding

5m

This step binds DNA fragments 100 bp and larger to the magnetic beads.

Pipette  45 µL of NGS Beads suspension with x8 multichannel pipette and transfer in digestion plate (plate with  45 µL of digested template DNA for each sample), carefully mix by pipetting up and down 10 times.

Incubate  00:05:00 at  Room temperature

16 Separation

5m

Place the purification plate onto the 96-well magnetic separator.

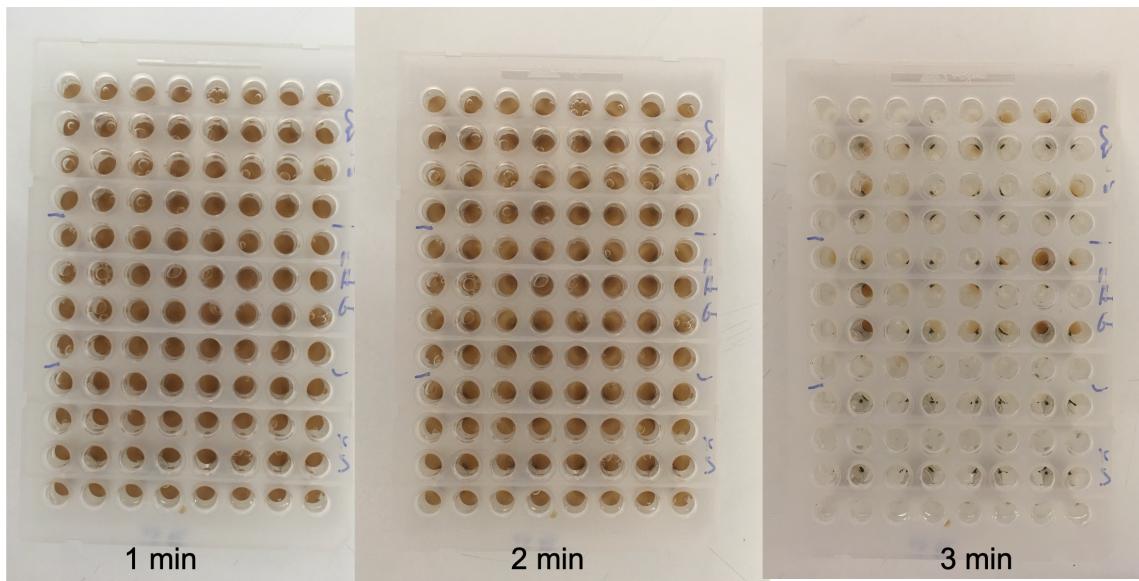
Wait at least  00:05:00 until all the beads have been attracted by the magnets or until the liquid appears clear.

The supernatant contains unwanted low molecular weight contaminants and unwanted smaller DNA fragments.

Remove and discard the supernatant (~90 µl) by pipetting.

Note

Do not disturb the attracted beads while aspirating the supernatant. Remove the supernatant with the multichannel from the opposite side of the well.



Example of separation process where beads have been attracted by the magnets

NucleoMag® SEP Macherey-Nagel Catalog #744900

17 **1st wash with 80 % ethanol**

Place 80% ethanol in a reagent reservoir.

With a x8 multichannel pipette, dispense  200 µL of 80% ethanol into the purification plate without disturbing the bead pellet.

Incubate the purification plate at room temperature for at least  00:00:30

Carefully and completely remove and discard ethanol by pipetting.

18 **2nd wash with 80 % ethanol**

With a x8 multichannel pipette, dispense  200 µL of 80% ethanol into the purification plate without disturbing the bead pellet.

Incubate the purification plate at room temperature for at least  00:00:30

Carefully and completely remove and discard ethanol by pipetting.

19 **Dry the beads**

Let the purification plate on the magnetic separator and incubate at  Room temperature for **maximum**  00:05:00 in order to allow the remaining traces of ethanol to evaporate.

Note

Take care not to over dry the bead pellet (bead pellet appears cracked in this case) as this will significantly decrease elution efficiency.

30s

5m

20 Elute DNA fragments

10m

Take the purification plate from the magnetic stand, and add $\text{40 } \mu\text{L}$ of nuclease-free water with a x8 multichannel pipette to resuspend the bead pellet by pipetting up and down 10 times.

Incubate the purification plate at Room temperature for $00:05:00$.

Separate the magnetic beads against the side of the wells by placing the 96-well plate on the magnetic separator.

Wait at least $00:05:00$ until all the beads have been attracted by the magnets or until the liquid appears clear.

Transfer $\text{35 } \mu\text{L}$ of the supernatant containing the digested purified template DNA to a new 96-well plate. **Be careful to avoid pipeting beads during this step.**

Seal the plate and store at $4 \text{ } ^\circ\text{C}$ (or store $-20 \text{ } ^\circ\text{C}$ for a long-term storage) until adaptor ligation.

Adaptor ligation

18h

- 21 For each sample of one line of the digested purified plate (with $\text{35 } \mu\text{L}$ of digested purified template DNA) add $\text{5 } \mu\text{L}$ of double-stranded barcoded P1 adaptors at 4 μM . **Use one double-stranded barcoded P1 adaptors per line.**

One P1 adapter per line.

	1	2	3	4	5	6	7	8	9	10	11	12
P1_PstI_01→	A dna-01	dna-02	dna-03	dna-04	dna-05	dna-06	dna-07	dna-08	dna-09	dna-10	dna-11	dna-12
P1_PstI_02→	B dna-13	dna-14	dna-15	dna-16	dna-17	dna-18	dna-19	dna-20	dna-21	dna-22	dna-23	dna-24
P1_PstI_03→	C dna-25	dna-26	dna-27	dna-28	dna-29	dna-30	dna-31	dna-32	dna-33	dna-34	dna-35	dna-36
P1_PstI_04→	D dna-37	dna-38	dna-39	dna-40	dna-41	dna-42	dna-43	dna-44	dna-45	dna-46	dna-47	dna-48
P1_PstI_05→	E dna-49	dna-50	dna-51	dna-52	dna-53	dna-54	dna-55	dna-56	dna-57	dna-58	dna-59	dna-60
P1_PstI_06→	F dna-61	dna-62	dna-63	dna-64	dna-65	dna-66	dna-67	dna-68	dna-69	dna-70	dna-71	dna-72
P1_PstI_07→	G dna-73	dna-74	dna-75	dna-76	dna-77	dna-78	dna-79	dna-80	dna-81	dna-82	dna-83	dna-84
P1_PstI_08→	H dna-85	dna-86	dna-87	dna-88	dna-89	dna-90	dna-91	dna-92	dna-93	dna-94	dna-95	dna-96

Map of plate with the P1 adaptors lines

Note

Depending on the number of samples you want to put into the library (maximum 576 samples), you can mix the number of barcoded P1 adaptors (one per lines) and the number of Illumina indexes (one per columns).



Plate #1

		1	2	3	4	5	6	7	8	9	10	11	12
Adapt_P1		A	DNA										
P1_Pt1_SM_01_F		B	DNA										
P1_Pt1_SM_02_F		C	DNA										
P1_Pt1_SM_03_F		D	DNA										
P1_Pt1_SM_04_F		E	DNA										
P1_Pt1_SM_05_F		F	DNA										
P1_Pt1_SM_06_F		G	DNA										
P1_Pt1_SM_07_F		H	DNA										

Plate #2

		1	2	3	4	5	6	7	8	9	10	11	12
Adapt_P1		A	DNA										
P1_Pt1_SM_09_F		B	DNA										
P1_Pt1_SM_10_F		C	DNA										
P1_Pt1_SM_11_F		D	DNA										
P1_Pt1_SM_12_F		E	DNA										
P1_Pt1_SM_13_F		F	DNA										
P1_Pt1_SM_14_F		G	DNA										
P1_Pt1_SM_15_F		H	DNA										

Plate #3

		1	2	3	4	5	6	7	8	9	10	11	12
Adapt_P1		A	DNA										
P1_Pt1_SM_17_F		B	DNA										
P1_Pt1_SM_18_F		C	DNA										
P1_Pt1_SM_19_F		D	DNA										
P1_Pt1_SM_20_F		E	DNA										
P1_Pt1_SM_21_F		F	DNA										
P1_Pt1_SM_22_F		G	DNA										
P1_Pt1_SM_23_F		H	DNA										

Plate #4

		1	2	3	4	5	6	7	8	9	10	11	12
Adapt_P1		A	DNA										
P1_Pt1_SM_01_F		B	DNA										
P1_Pt1_SM_02_F		C	DNA										
P1_Pt1_SM_03_F		D	DNA										
P1_Pt1_SM_04_F		E	DNA										
P1_Pt1_SM_05_F		F	DNA										
P1_Pt1_SM_06_F		G	DNA										
P1_Pt1_SM_07_F		H	DNA										

Plate #5

		1	2	3	4	5	6	7	8	9	10	11	12
Adapt_P1		A	DNA										
P1_Pt1_SM_09_F		B	DNA										
P1_Pt1_SM_10_F		C	DNA										
P1_Pt1_SM_11_F		D	DNA										
P1_Pt1_SM_12_F		E	DNA										
P1_Pt1_SM_13_F		F	DNA										
P1_Pt1_SM_14_F		G	DNA										
P1_Pt1_SM_15_F		H	DNA										

Plate #6

		1	2	3	4	5	6	7	8	9	10	11	12
Adapt_P1		A	DNA										
P1_Pt1_SM_17_F		B	DNA										
P1_Pt1_SM_18_F		C	DNA										
P1_Pt1_SM_19_F		D	DNA										
P1_Pt1_SM_20_F		E	DNA										
P1_Pt1_SM_21_F		F	DNA										
P1_Pt1_SM_22_F		G	DNA										
P1_Pt1_SM_23_F		H	DNA										

Number and map of plates with combination of barcoded P1 adaptors and Illumina Indexes depending on the number of samples required into the library.

22 Vortex all reagents, except enzymes (stored at -20 °C), for approximately 00:00:05 20m

Spin down all reagents for approximately 00:00:05 and place On ice.

In a microtube, prepare the ligation mix, according to the following table for a total volume of

60 µL :

A	B	C	D	E
Digested purified template D NA + P1 adaptor		Initial concentration	Final concentration	n=1
P2 adaptor (Hhal or Msel)	40 µM	330 nM	0.5 µL	50 µL
T4 ligase buffer	10X	1X	6 µL	600 µL

A	B	C	D	E
T4 ligase	400 u/µL	160U	0.4 µL	40 µL
nuclease-free water			13.1 µL	1310 µL
TOTAL			60 µL	2000 µL

Ligation master mix composition

- 23 Vortex the master mix and spin down.

17h

Aliquot  125 µL of the ligation master mix in each well of two 8-PCR tube strip.

In the digested purified plate (containing  35 µL of digested purified template DNA and  5 µL of barcoded P1 adaptors), add  20 µL of ligation master mix with a x8 multichannel pipette and mix by pipetting, seal PCR plate and spin down.

Incubate at  16 °C  Overnight

Then store at  4 °C or at  -20 °C if not performing the bead purification the day after.

Bead purification (96-well plate format)

1h

24 Before starting

Prepare  50 mL of fresh 80% Molecular Biology Grade Ethanol

 40 mL Molecular Biology Grade Ethanol

 10 mL nuclease-free water

 Ethanol, Absolute, Molecular Biology Grade **Thermo Fisher Scientific Catalog #BP2818500**

Remove the NucleoMag® NGS Bead Suspension from the fridge. Let for approximately 30 min to bring the bead suspension to  Room temperature .

Then, vortex this Bead Suspension stock solution carefully until homogenized and put in a reagent reservoir.

 NucleoMag kit for clean up and size selection of NGS library prep reactions **Macherey-Nagel Catalog #744970.50**

25 Binding

This step binds DNA fragments 100 bp and larger to the magnetic beads.

Pipette  60 µL of NGS Beads suspension with x8 multichannel pipette and transfer in adaptor-ligated plate (plate with  60 µL of digested and adaptor-ligated template DNA for each sample), carefully mix by pipetting up and down 10 times.

Incubate  00:05:00 at  Room temperature

26

Separation

Place the purification plate onto the 96-well magnetic separator.

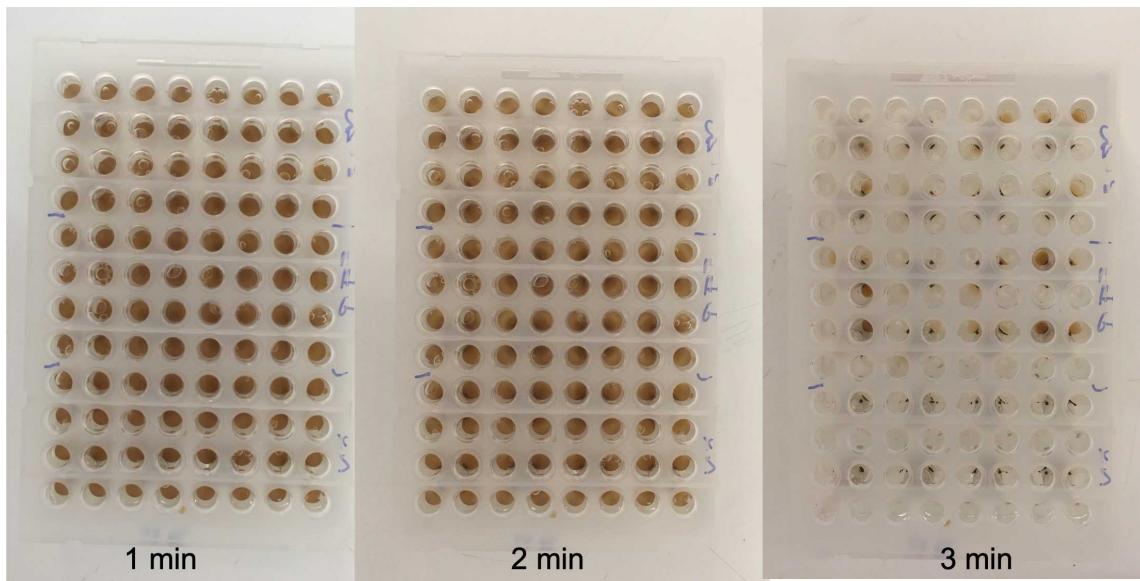
Wait at least  00:05:00 until all the beads have been attracted by the magnets or until the liquid appears clear.

The supernatant contains unwanted low molecular weight contaminants and unwanted smaller DNA fragments.

Remove and discard the supernatant (~120 µl) by pipetting.

Note

Do not disturb the attracted beads while aspirating the supernatant. Remove the supernatant with the multichannel from the opposite side of the well.



Example of separation process where beads have been attracted by the magnets

NucleoMag® SEP Macherey-Nagel Catalog #744900

27 1st wash with 80 % ethanol

Place 80% ethanol in a reagent reservoir.

With a x8 multichannel pipette, dispense  200 µL of 80% ethanol into the purification plate without disturbing the bead pellet.

Incubate the purification plate at room temperature for at least  00:00:30

Carefully and completely remove and discard ethanol by pipetting.

28 2nd wash with 80 % ethanol

With a x8 multichannel pipette, dispense  200 µL of 80% ethanol into the purification plate without disturbing the bead pellet.

Incubate the purification plate at room temperature for at least  00:00:30

Carefully and completely remove and discard ethanol by pipetting.

29 Dry the beads

Let the purification plate on the magnetic separator and incubate at  Room temperature

for maximum  00:05:00 in order to allow the remaining traces of ethanol to evaporate.

Note

Take care not to over dry the bead pellet (bead pellet appears cracked in this case) as this will significantly decrease elution efficiency.

30 Elute DNA fragments

10m

Take the purification plate from the magnetic stand, and add  40 µL of nuclease-free water with a x8 multichannel pipette to resuspend the bead pellet by pipetting up and down 10 times.

Incubate the purification plate at  Room temperature for  00:05:00 .

Separate the magnetic beads against the side of the wells by placing the 96-well plate on the magnetic separator.

Wait at least  00:05:00 until all the beads have been attracted by the magnets or until the liquid appears clear.

Transfer  35 µL of the supernatant containing the adaptor-ligated purified template DNA to a new 96-well plate. **Be careful to avoid pipeting beads during this step.**

Seal the plate and store at  4 °C (or store  -20 °C for a long-term storage) until PCR amplification.

Rad Tag enrichment (PCR)

3h

31 PCR amplification to generate Illumina sequencing indexed libraries :

In this PCR, Illumina indexed primers are incorporated in order to produce fragments compatible with Illumina sequencing, and to insert an index allowing multiplexing of barcoded samples. This index will be read during the sequencing run.

This PCR is expected to have a homogenizing effect. Primers are thus included in limiting quantity, in order to produce equalized amounts of PCR fragments among samples. The number of cycles is limited to a maximum of 15 (optimal with 12). After those cycles, a final PCR cycle is then performed after addition of primers in large excess.

The Reaction mixture for a total volume of  40 µL is :

A	B	C	D
	Initial concentration	Final concentration	n=1
Adaptor-ligated purified template DNA			10 µL
Primer mix (ILLPCR1 and ILLPCR2ind)	5 µM each	0.17 µM	1.36 µL
Q5 buffer	5X	1X	8 µL
High GC enhancer	5X	1X	8 µL
dNTP mix	25mM each	0.20 µM	0.32 µL
Q5 hotstart hifi polymerase	2 u/µL	0.8 U	0.40 µL
nuclease-free water			11.92 µL
Total mix			30 µL
TOTAL reaction			40 µL

PCR mixture composition

We need to prepare one PCR mixture per index, i.e. 12 PCR mixtures for one plate.

One IIIPCR 2 index per column.

	IIIPCR2 Ind01	IIIPCR2 Ind02	IIIPCR2 Ind03	IIIPCR2 Ind04	IIIPCR2 Ind05	IIIPCR2 Ind06	IIIPCR2 Ind07	IIIPCR2 Ind08	IIIPCR2 Ind09	IIIPCR2 Ind10	IIIPCR2 Ind11	IIIPCR2 Ind12	
	1	2	3	4	5	6	7	8	9	10	11	12	
P1_PstI_01→	A	dna-01	dna-02	dna-03	dna-04	dna-05	dna-06	dna-07	dna-08	dna-09	dna-10	dna-11	dna-12
P1_PstI_02→	B	dna-13	dna-14	dna-15	dna-16	dna-17	dna-18	dna-19	dna-20	dna-21	dna-22	dna-23	dna-24
P1_PstI_03→	C	dna-25	dna-26	dna-27	dna-28	dna-29	dna-30	dna-31	dna-32	dna-33	dna-34	dna-35	dna-36
P1_PstI_04→	D	dna-37	dna-38	dna-39	dna-40	dna-41	dna-42	dna-43	dna-44	dna-45	dna-46	dna-47	dna-48
P1_PstI_05→	E	dna-49	dna-50	dna-51	dna-52	dna-53	dna-54	dna-55	dna-56	dna-57	dna-58	dna-59	dna-60
P1_PstI_06→	F	dna-61	dna-62	dna-63	dna-64	dna-65	dna-66	dna-67	dna-68	dna-69	dna-70	dna-71	dna-72
P1_PstI_07→	G	dna-73	dna-74	dna-75	dna-76	dna-77	dna-78	dna-79	dna-80	dna-81	dna-82	dna-83	dna-84
P1_PstI_08→	H	dna-85	dna-86	dna-87	dna-88	dna-89	dna-90	dna-91	dna-92	dna-93	dna-94	dna-95	dna-96

Map of plate with the Illumina indexes columns



Q5 Hot Start High-Fidelity DNA Polymerase - 500 units **New England Biolabs Catalog #M0493L**

32 First PCR mix preparation (with primers in limiting quantity)

Defreeze and vortex all reagents, except enzymes (stored at -20°C), for approximately

⌚ 00:00:05

Spin down all reagents for approximately ⌚ 00:00:05 and place 🍦 On ice .

30m

In 12 🧪 0.5 mL microtubes, prepare the 1st mix according to the following table (one mix per column) :

A	B	C	D	E
	Initial concentrat	Final concentrat	n=1	n=10 (one column of 1 plate)
Adaptor-ligated purified tem plate DNA			10 µL	
Primer mix (ILLPCR1 and ILL PCR2ind)	5 µM each	0.17 µM	1.36 µL	13.6 µL
Q5 buffer	5X	1X	8 µL	80 µL
High GC enhancer	5X	1X	8 µL	80 µL
dNTP mix	25mM each	0.20 µM	0.32 µL	3.2 µL
Q5 hotstart hifi polymerase	2 u/µL	0.8 U	0.40 µL	4 µL
nuclease-free water			11.92 µL	119.2 µL
TOTAL			30 µL	300 µL

PCR mix composition

Vortex mix all reagents in the mix and spin down.

In a new PCR plate, dispense  30 µL of 1st mix in each column.

33 DNA and mix combination

1h 30m

Spin down the adaptor-ligated purified template DNA plate.

With a multichannel pipette, transfer  10 µL of adaptor-ligated purified template DNA into the PCR plate and mix by pipetting.

Finally, aliquot the  40 µL of the total mix by dispensing  20 µL into 1 additional new empty PCR plates.

Seal the 2 PCR plates and spin down.

The 2 PCR will be performed in parallel in 2 different thermal cyclers, in order to reduce the PCR bias.

A	B	C	D
Cycle step	Temperature	Time	Cycles
Hot start initial denaturation	98°C	30 sec	1
Denaturation	98°C	20 sec	15
Annealing	60°C	30 sec	15
Extension	72°C	40 sec	15
Final extension	72°C	10 min	1
Hold	4°C		

PCR program for the Illumina indexing PCR

After PCR, pool back the 2 PCR plates into a single plate with a multichannel

34 Final cycle (with primers in large excess)

1h

In a 12-tube PCR strip, prepare the 2nd mix according to the following table (one mix per column) :

A	B	C	D	E
	Initial concentration	Final concentration	n=1	n=10 (one column of 1 plate)

A	B	C	D	E
Primer mix (ILLPCR1 and ILPCR2ind)	5 µM each	3.35 µM	2.68 µL	26.8 µL
Q5 buffer	5X	1X	0.80 µL	8 µL
dNTP mix	25mM each	0.20 µM	0.32 µL	3.2 µL
nuclease-free water			0.20 µL	2 µL
TOTAL			4 µL	40 µL

Final cycle PCR mix composition

Mix all reagents by pipetting and spin down.

Dispense  4 µL of final cycle mix in each line of the PCR plate with a 12 multichannel pipette.

Seal the PCR plate and spin down.

In a thermocycler, run the final cycle as follows :

A	B	C	D
Cycle step	Temperature	Time	Cycles
Denaturing	98°C	3 min	1
Annealing	60°C	2 min	1
Extension	72°C	12 min	1
Hold	12°C		

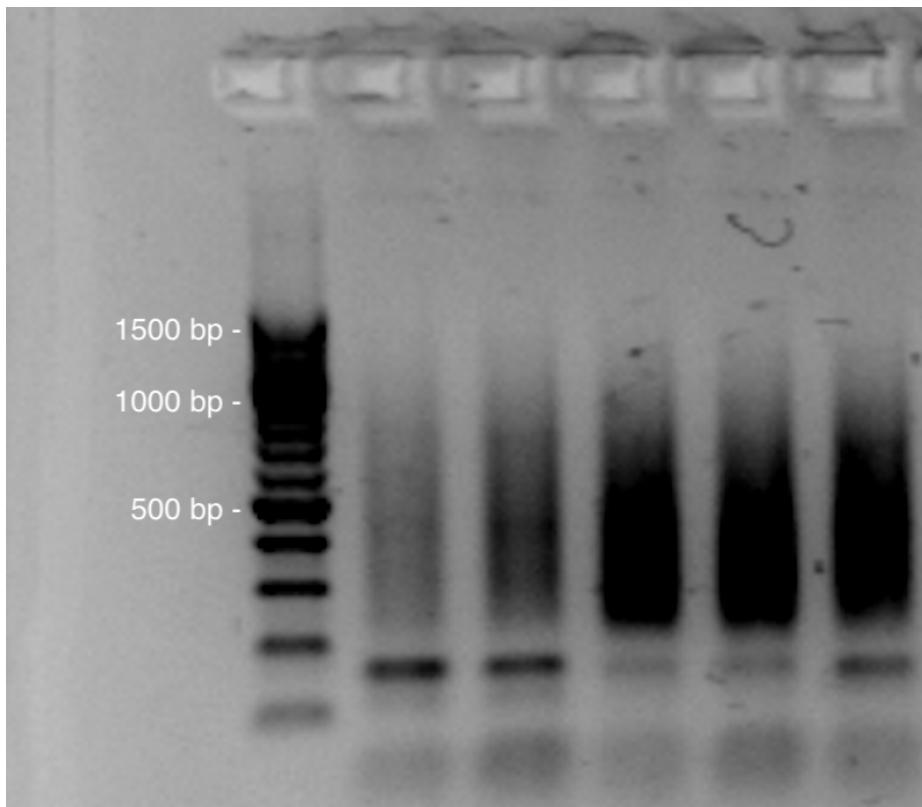
PCR program for the final cycle of the illumina PCR

After PCR, place the plate at  4 °C (or  -20 °C for a long-term storage).

Check PCR on an agarose gel

1h

- 35 Check the efficiency of the PCR by electrophoresis of  5 µL of digested DNA in a 1.5 % agarose gel (standard quality).



Example of smears obtained after the Illumina PCR.
Size marker is a 100bp ladder.

Sample pooling (equimolar)

30m

- 36 Each barcoded and indexed individual can now be pooled in a single tube, in equimolar conditions.

After the normalizing PCR, all smears should have similar intensity on the agarose gel. In this case, pool $\text{5 } \mu\text{L}$ of all individuals in a single low binding 1.5 mL microtube.

If not, normalization can be made at this step. For this, roughly estimate the concentration of fragments from the gel picture, and pools accordingly. It can be efficient to make intermediate pools for example, one pool for the low, one for the medium, and another one for the high intensity samples in 3 low binding 1.5 mL microtubes .

Vortex mix and spin down.

Store at 4°C (or -20°C for a long-term storage) until bead purification.

Bead purification (microtube format)

37 Before starting

Prepare  10 mL of fresh 80% Molecular Biology Grade Ethanol

 8 mL Molecular Biology Grade Ethanol

 2 mL nuclease-free water

 Ethanol, Absolute, Molecular Biology Grade **Thermo Fisher Scientific Catalog #BP2818500**

Remove the NucleoMag® NGS Bead Suspension from the fridge. Let for approximately 30 min to bring the bead suspension to  Room temperature .

Then, vortex this Bead Suspension stock solution carefully until homogenized and put in a reagent reservoir.

 NucleoMag kit for clean up and size selection of NGS library prep reactions **Macherey-Nagel Catalog #744970.50**

38 Binding

This step binds DNA fragments 100 bp and larger to the magnetic beads.

Pipette a volume of NGS Beads suspension to have a ratio 1:1 with the sample pooling volume, and transfer in the pooling sample tube(s).

Carefully mix by pipetting up and down 10 times.

Incubate  00:05:00 at  Room temperature

39 Separation

Place the purification tube(s) onto the magnetic microtube stand.

Wait at least  00:05:00 until all the beads have been attracted by the magnets or until the liquid appears clear.

The supernatant contains unwanted low molecular weight contaminants and unwanted smaller DNA fragments.

Remove and discard the supernatant by pipetting.

Note

Do not disturb the attracted beads while aspirating the supernatant. Remove the supernatant with the pipette from the opposite side of the well.



Rack de séparation MagJET, 12 tubes de 1,5 ml Thermo Fisher
Scientific Catalog #MR02

40 1st wash with 80 % ethanol

Dispense 1 mL of 80% ethanol into the purification tube(s) without disturbing the bead pellet.

Incubate the purification tube(s) at room temperature for at least 00:00:30

Carefully and completely remove and discard ethanol by pipetting.

41 2nd wash with 80 % ethanol

Dispense 1 mL of 80% ethanol into the purification tube(s) without disturbing the bead pellet.

Incubate the purification tube(s) at room temperature for at least 00:00:30

Carefully and completely remove and discard ethanol by pipetting.

42 Dry the beads

Let the purification tube(s) on the magnetic separator and incubate at Room temperature for maximum 00:05:00 in order to allow the remaining traces of ethanol to evaporate.

Note

Take care not to over dry the bead pellet (bead pellet appears cracked in this case) as this will significantly decrease elution efficiency.

43 Elute DNA fragments

Take the purification tube(s) from the magnetic stand, and add 100 µL of nuclease-free water with a pipette to resuspend the bead pellet by pipetting up and down 10 times.

Incubate the purification tube(s) at Room temperature for 00:05:00.

Separate the magnetic beads against the side of the tube by placing the tube(s) on the magnetic separator.

10m

Wait at least  00:05:00 until all the beads have been attracted by the magnets or until the liquid appears clear.

Transfer  90 μL of the supernatant in a new(s) low binding  1.5 mL microtube(s). **Be careful to avoid pipeting beads during this step.**

Store at  4 °C (or store  -20 °C for a long-term storage) until size selection.

Intermediate pools quantification and final pooling (Optional)

30m

- 44 If you made intermediate pools (low, medium and high intensity on agarose gel), estimate the double strand DNA concentration in the pools by fluorimetry with a Qubit equipment.

 Qubit_dSDNA_HS_Assay_UG.pdf 229KB

Pool in equimolar concentration the 3 intermediate pools in a single low binding  1.5 mL microtube with a minimum concentration of  20 nanomolar (nM) and minimum volume of  30 μL .

Vortex mix and spin down.

Store at  4 °C (or  -20 °C for a long-term storage) until size selection.

Size selection with sage science Pippin-Prep

2h

- 45 Perform the size selection of fragments between 300 and 800 bp using a 1,5% DF marker K agarose gel cassette, according to the Pippin prep manufacturer's instructions :

 Pippin-prep-Quick-Guide-CDF1510-... 636KB

Note

In the case you do not have access to a Pippin prep, you can alternatively perform a double size-selection with beads (see the bead manufacturer's instructions for details), or by smear excision and purification from an agarose gel. From our experience, size selection with the Pippin prep is the most accurate and repeatable method.

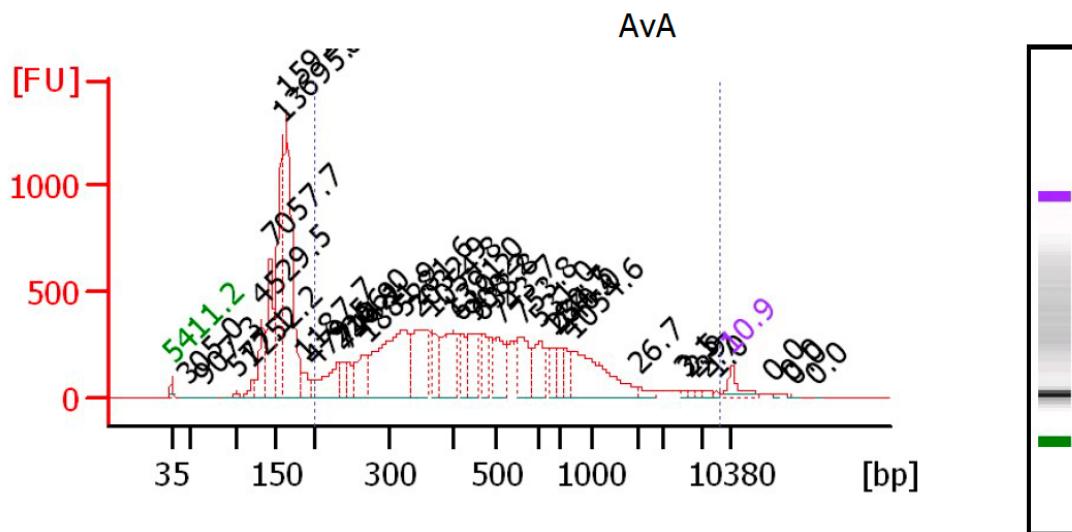
Quality control of the libraries

3h 30m

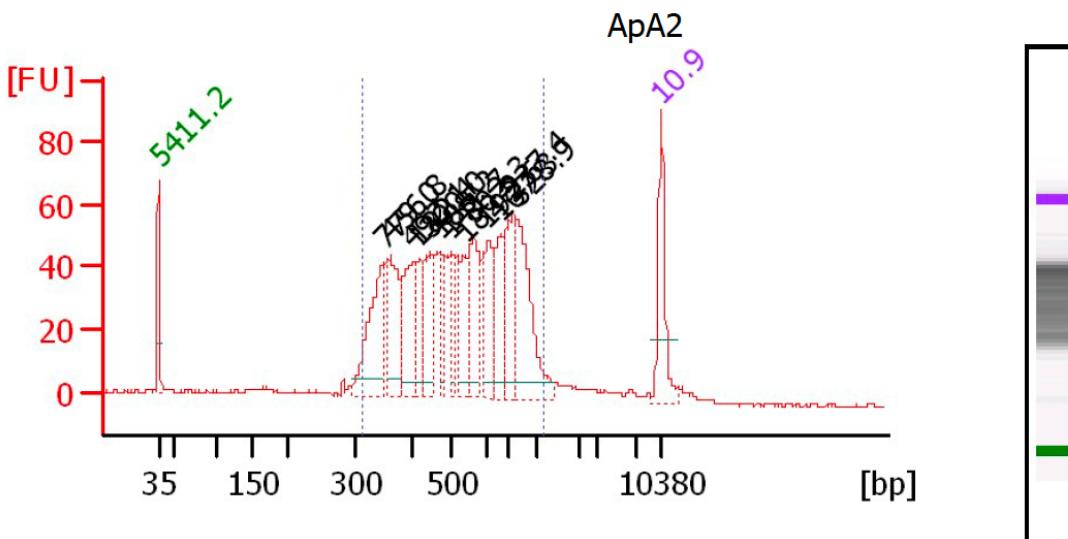
1h

- 46 Control the quality of the library** with a Bioanalyzer (Agilent) (or equivalent equipment) in a High Sensitivity DNA chip. Dilute your pool 1:2 or more and load 1 μ l of the pool before and after size selection, according to the manufacturer's instructions :

 Agilent_high_SensitivityDNA_KG_EN... 6MB



Example of a Bioanalyzer profile obtained for a ddRADseq library **before size selection** (DNA HS kit)



Example of a Bioanalyzer profile obtained for a ddRADseq library **after size selection** (DNA HS kit)

47 Fluorimetric estimation of the dsDNA concentration in the library.

Perform a quick estimation of the DNA concentration with a fluorimetric assay, in a Qubit™ apparatus or equivalent, with the Qubit ds 1X DNA HS assay kit, according to the manufacturer's instructions:

30m



Qubit_dsdNA_HS_Assay_UG.pdf 229KB

48 qPCR quantification

2h

In the case you need an accurate estimation of the DNA concentration in your library, perform a qPCR quantification with the NEBNext Library Quant Kit for Illumina, or equivalent, which uses P5 and P7 illumina primers to target the double stranded DNA fragments in the library. Follows the kit's user guide and perform your quantitative qPCR in a qPCR thermocycler (e.g. LightCycler 480, Roche).



NEBNext_manualE7630.pdf 2.6MB

Contrarily to the fluorimetric method (Qubit), the qPCR estimation will only consider dsDNA fragments starting with P5 and ending with P7 illumina sequences, that will be effectively amplified onto the flowcell of the Illumina sequencer.

48.1 Suggestions to prepare library dilutions for qPCR

In  0.5 mL low binding microtube, prepare 1:1 000 dilution of library with buffer supplied in the qPCR kit. Then, prepare the 3 library dilutions (1:10 000 to 1:30 000) to be used on triplicate

for qPCR analysis.

1:100 :  1 μ L of library +  99 μ L of 1X buffer

1:1 000 :  10 μ L of library +  90 μ L of 1X buffer

1:10 000 :  20 μ L of 1:1 000 dilution +  180 μ L of 1X buffer

1:20 000 :  50 μ L of 1:10 000 dilution +  50 μ L of 1X buffer

1:30 000 :  50 μ L of 1:10 000 dilution +  100 μ L of 1X buffer

You should get more than 10 nM, that is the library concentration usually required by the sequencing platform facilities.

Use the average size of the library size range as estimated from the Bioanalyzer profile to convert DNA concentration from nM to ng/ μ L using the attach file below :



nM_ng μ L_Conversion_Calculator.xlsx 14KB

49 Library ready for sequencing

The library is now ready for sequencing in single read or paired-end 150 bases in an Illumina sequencer, with one index read.