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Protocol for monitoring and data analysis of sea-surface plastics in Citizen Science projects, including the construction of a low-cost instrument to collect plastic debris

SeaPaCS – Participatory Citizen Science against Marine Pollution and Climate Change

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1. How to build a DIY *LADI* (Low-Tech Aquatic Detection Debris Instrument)

This protocol is adapted from "*LADI and the Trawl*" by Coco Coyle with Melissa Novaceski, Emily Wells and Max Liboiron, as published by the Civic Laboratory for Environmental Action Research, August 2016 (hereby referred to as "*original document*", freely available at https://civiclaboratory.nl/2016/06/29/ladi-trawl/).
A video tutorial of the procedure is available at https://www.youtube.com/watch?v=kORl4GDr1Fc and was produced by SeaPaCS (https://crowdusg.net/seapacs/) in collaboration with the non-profit organization "Terra nel Cuore" (https://terranelcuore.it/).

The initial idea was to replicate the *LADI* trawl as proposed by the authors of the *original document*, following a step-by-step procedure for specific technical details as well as for the materials' choice. The final protocol has however some minor deviations from the *original document*, which have been adjusted to accommodate the specific objectives of SeaPaCS project, the end-users of the *LADI* trawl within SeaPaCS, and the availability of materials and project's needs for citizen science research in the coastal city of Anzio, south of Rome (Italy).

Deviations from the *original document* are described in each single construction phase of the *LADI*. Other references consulted include: GESAMP (2019). Guidelines or the monitoring and assessment of plastic litter and microplastics in the ocean (Kershaw P.J., Turra A. and Galgani F. editors), (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP/ISA Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Rep. Stud. GESAMP No. 99, 130p

1.1 Materials and costs

All materials can be easily found in hardware stores. D = diameter.

Material	**cost (€)**
Fir bead board 1.8 mm x 14.5 cm x 3 m	10.00
Fir bead board trimming work	10.00
Mahogany colored primer	9.00
Water-repellent finish for wood	12.00
Rope 30 m D 5 mm	6.40
Rope 10 m D 4 mm	3.00
PVC pipes 3 m D 63 mm + 12 PVC rigid slide caps D 63 mm	49.20
Glue for PVC (Tangit)	8.70
Silicone tube	3.00
10 x 6cm D 6mm bolts with nuts and washers	3.00
2 metal cable ties D 14 cm	1.80
Rope 30 m D 6 mm	8.00
Mosquito net 2 m x 1.50 m	8.00
PVC pipe 18.5 cm D 13 cm	10.00
3 steel eyelets	3.00
5 carabiners	12.50
1 steel ring	1.00
8 steel corners to reinforce	4.00
12 x 6 cm screws	2.00
20 x 1 cm screws	1.50
TOTAL COST	**166.10**
Other material purchased and not used	
2 net sheets 1 m x 2 m 250 micron	25.74
2 net sheets 1 m x 2 m 60 micron	34.00

1.2 Building the “mouth”

For the mouth, we used:

- 1 fir bead board of 1.8 cm (thickness) x 14.5 cm (width) x 3 m (length)
- 1 can of impregnating sealant, mahogany color (primer)
- 1 can of water-repelling wood finish
- 10 bolts of 6 cm and 6 mm in diameter, with nuts and washers
- 6 rigid PVC end caps of 63 mm diameter.

1.2.1

First of all, the two lateral edges intended for jointing were removed from the fir board in the carpentry shop. Then, from the trimmed bead the following 8 tablets were obtained, 1.8 cm thick and 12.5 cm wide (Figure 1):

- 2 boards of 38 cm for the upper and lower sides of the external rectangle of the mouth;
- 2 boards of 30.5 cm for the right and left side of the external rectangle;
- 2 boards of 33.5 cm for the upper and lower sides of the internal rectangle;
- 2 boards of 26 cm for the right and left side of the internal rectangle.

1.2.2

The 8 boards were treated with 3 coats of mahogany-colored primer and, after they were completely dried, covered with a water-repellent finish for wood (Figure 2).

Figure 1. Trimming the edges of the fir boards

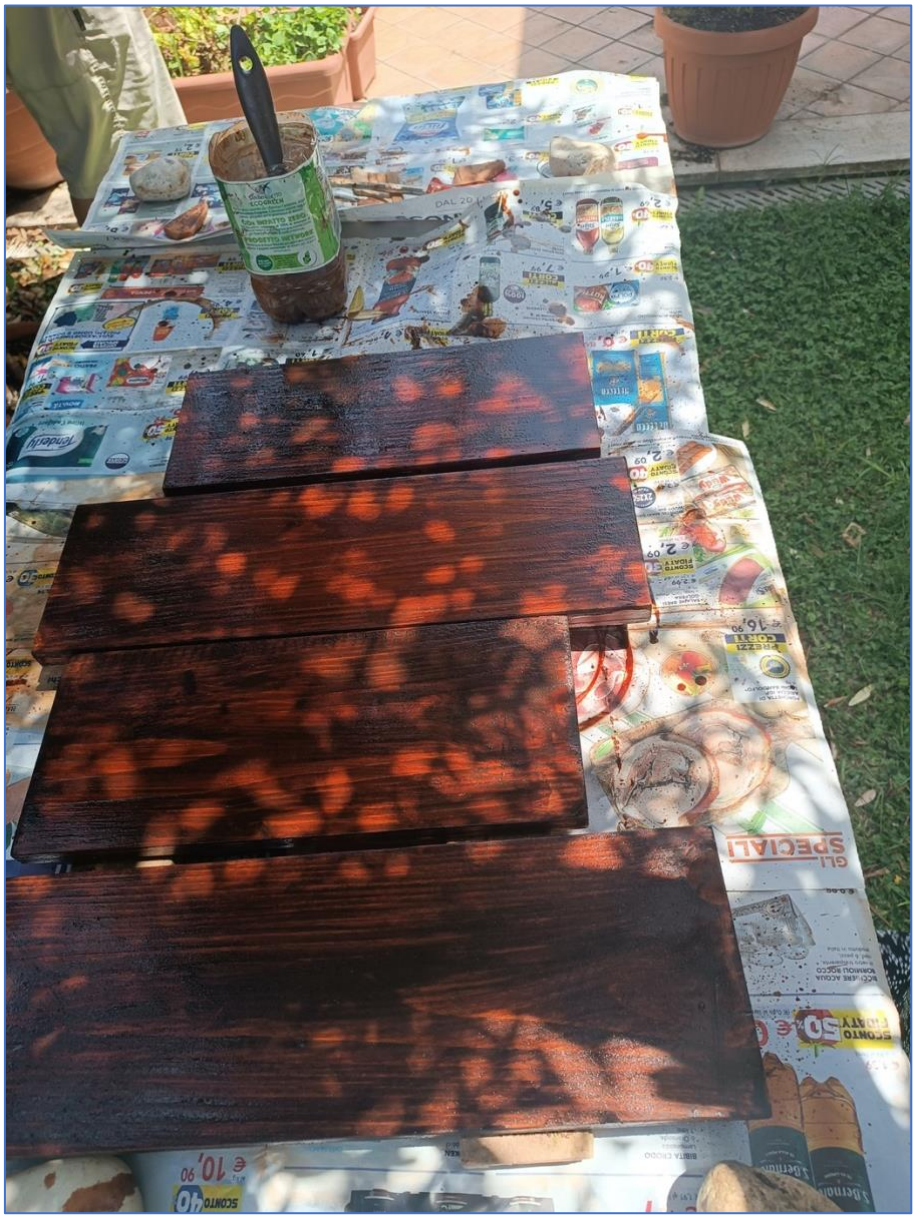

Figure 2. Coating with mahogany primer

1.2.3

The assembly of the external rectangle of the LADI mouth followed the indications of the *original document*, but considering that the structure was made with soft wood, to make it more solid, the following variations were made (Figure 3):

- 3 x 6 cm screws were used for each corner (instead of the 2 suggested);
- the four front corners and the four rear corners of the external rectangle were reinforced with steel corners, 1.5 cm wide and 5 cm long on each side, fixed with 1 cm screws.

Figure 3. The mouth: external rectangle

1.2.4

Subsequently, we marked the central point of the board on the right side of the external rectangle where we fixed an end cap perfectly centered on that point with one of the 6 cm bolts.

1.2.5

Afterwards, two caps were fixed next to it: the three caps in a row were placed with a backward inclination (towards what will be the net of the *LADI*) of about 7 degrees on the right side of the rectangle. The same operation was done on the left side of the rectangle.

1.2.6

Once the holes were drilled, bolts and caps were removed from the right and left sides of the outer rectangle to proceed with placing the inner rectangle.

1.2.7

The 4 boards for the internal rectangle were placed perfectly centered inside (2 boards of 33.5 cm for the upper and lower part, and 2 boards of 26 cm for the inner left and right sides). These internal boards were fixed with clamps.

1.2.8

In the next step, we measured 12 cm from the right and left edges of the upper side of the external rectangle where we drilled 2 holes for 2 bolts of 6 cm each. The same operation was repeated on the lower side of the outer rectangle.

1.2.9

On the lateral (right and left) sides of the outer rectangle the 3 holes previously drilled for the caps (1.2.5) were drilled deeper to reach the internal rectangle structure.

1.2.10

The two rectangles (external and internal one) were jointed with 10 bolts of 6 cm each: 2 bolts on the upper and lower boards each, and 3 bolts with caps on the right and left sides of the whole mouth structure.

1.2.11

During the assembly, a strap was inserted under the head of the bolts on the upper side of the outer rectangle to ease the handling and transport of the structure (Figure 4).

1.2.12

After joining the two rectangles of the mouth together (inner and outer), the end caps and bolts were fixed again on the lateral sides of the outer rectangle (as in 1.2.5) that will later host the tubes constituting the wings (see 1.3) (Figure 5).

Figure 4. The strap fixed on the upper outer rectangle side, to ease the handling of the device.

1.3 Building the wings

To build the wings we used:

- 6 x rigid 63 mm PVC sled caps
- 1 x 3 m PVC pipe with 63 mm diameter
- 10 meters of 4 mm diameter rope
- 30 meters of 5 mm diameter rope

- 1 transparent silicone cartridge
- 1 tube of PVC glue (Tangit® brand)

1.3.1

After covering the heads of the bolts inside the caps on the right and left side of the structure with a layer of silicone, the 3 m PVC pipe was divided into 6 parts of 50 cm, where 3 tubes will be joint together to form each one of the two wings of the *LADI*. Each wing will then have a length of about 50 cm.

1.3.2

The 6 pieces obtained were glued in the 6 caps already bolted on the structure (3 per each side of the outer rectangle, right and left, see 1.2.5) and closed at the other end by gluing the remaining 6 end caps. As specified previously by the inclination of the caps on the sides of the outer rectangle, the wings so obtained are inclined of about 7 degrees towards the back-lower end of the *LADI* mouth.

1.3.3

The following day, the caps were sealed to the respective tubes with silicone.

1.3.4

After about 24 hours, the three tubes composing each of the two wings were tied together (as illustrated in the *original document*) using approximately 5 meters of 4 mm diameter rope near the central body of the structure, and approximately 15 meters of 5 mm diameter rope in the outermost part which is the most subject to physical stress during towing at sea (Figure 6).

Figure 5. The mouth rectangles (inner and outer), with the central end cap bolted on the outer rectangle. This end cap hosts the central tube of the three tubes that constitute each of the wings of the LADI.

Figure 6. Fixing the wings with ropes.

1.4 Building the net

Considering that for the objectives of SeaPaCS project the *LADI* device will be deployed in an educational context, it was decided to use a net with a sufficiently large mesh size to allow the visual detection of microplastics by citizens without a microscope.

The net chosen is a standard nylon net for mosquitos, that indicatively has a mesh size of 1 mm. Smaller mesh sizes are also easily available for the interested users (60 and 250 microns).

For the net we used:

- A nylon mosquito net of 150 cm x 165 cm
- A tearproof nylon fabric of 180 cm x 13 cm

The construction procedure of the net, except for some adjustments in the sewing process, was essentially the one indicated in the *original document* (Coyle et al. 2016). We recommend using a sewing machine.

The final product was a tubular structure like a truncated cone with the following dimensions (Figure 7):

- greater base circumference of 134 cm
- smaller base circumference of 41 cm
- height 150 cm

Figure 7. The net.

1.5 Building the cod end

The cod end is the final collector of plastic fragments. It is attached to the main net and gets removed after each sampling. Plastic fragments are collected inside and can be removed and inspected once back on port. The material needed for the construction of the cod end was (Figure 8):

- a nylon mosquito net of 45 cm x 60 cm;
- a tearproof nylon fabric of 45 cm x 8 cm.

Except for some adjustments in the sewing procedure, the building of the cod end essentially followed the one indicated in the *original document* (Figure 9).

Figure 8. The parts of the cod end.

The final product was a mesh bag of 30 cm long with an opening circumference of 41 cm reinforced inside and outside with 8 cm of tearproof nylon fabric. Since it is very easy to lose the cod end at sea, we recommend building an extra one to bring along in every sampling, in case of necessity.

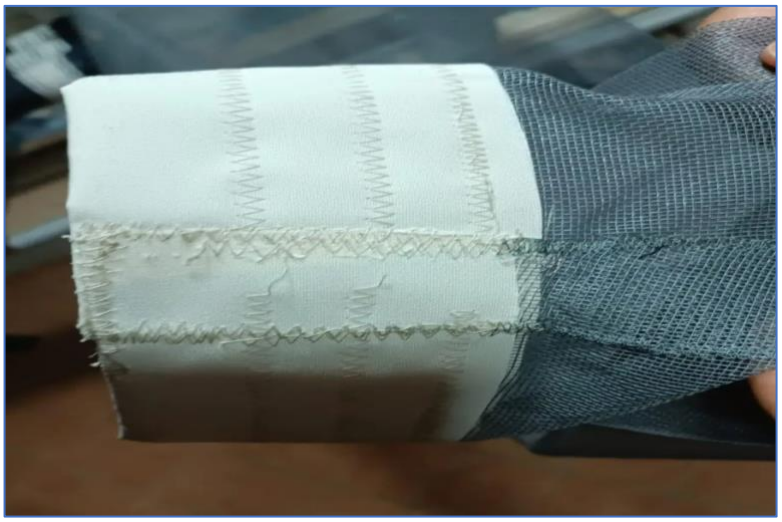

Figure 9. Detail on how the tearproof nylon fabric and the net were sewed together.

1.6 Assembling the complete *LADI* trawl device

For the assembly of the different parts of the *LADI* the following parts were necessary (Figure 10, Figure 11):

- 1 PVC pipe of 18.5 cm length and 12.5 cm in diameter;
- 2 steel hose clamps of 14 cm diameter each.

1.6.1

First, the widest edge of the net was positioned inside the mouth. On this edge of the net the points corresponding to the 10 x 6 cm bolts (on the mouth) were marked. A hole sufficient for the bolt to pass through was then hot-drilled on each marking on the net.

1.6.2

The next step consisted in unscrewing the nuts of the bolts inside the mouth and extracting the boards of the internal rectangle. The bolts were left in place and the edge of the mesh was inserted onto the bolts through the holes previously drilled.

1.6.3

At this point, the boards of the entire edge of the inner rectangle were reinserted into the bolts and held firmly together with the relative nuts.

1.6.4

Subsequently, we screwed three eyelets on the front part of the mouth structure (the first two, vertically, on the upper side of the external rectangle approximately 5 cm from the right and left edges and the third, horizontally, perfectly centered on the front edge of the lower panel of the external rectangle). The tow ropes of the *LADI* device will be attached on one side on the boat, and on the LADI they will be attached to these three eyelets through carabiners.

1.6.5

Finally, the 18.5 cm PVC pipe was used, together with the two steel hose clamps, to connect the net with the cod end.

Figure 10. The complete LADI device. Note the left wing has a backward inclination towards the lower back-end of the structure of about 7 degrees. This allows the mouth to stay afloat.

Figure 11. The front of the LADI device with the three eyelets visible, on which the carabiners of the towing ropes will be attached.

2. How to sample plastics at sea with the LADI trawl

2.1 Before starting your trip

a) Download a location tracker app that uses GPS, and doesn't require cell service (as an example MapMyRun by Under Armor, which is free on iOS and Android);
b) Check whether you can attach the *LADI* trawl laterally to the boat, trawling it alongside to avoid the wake, by using an arm, or alternatively you can use a flagpole or a wooden plank that stick out (Figure 12);
c) Check that the stern of the boat you will use has some hooks where you can attach the ropes that will trawl the *LADI* and that can withstand its drag;
d) Check the weather before planning the trip, and dress appropriately: be ready to spend some time in the water under the sun;
e) Observe plastic debris on the surface of the water as well as stranded along the coast the days before your trip, to have an idea on how much plastic you might expect to find;
f) Check the wind: sampling should be conducted in relatively calm sea conditions with a wave height less than 0.4 m, or less than Beaufort Sea State 2 (Figure 13).

Figure 12. A trawling arm to trawl the LADI laterally and avoid the wake. Image from "LADI and the Trawl" by Coco Coyle with Melissa Novaceski, Emily Wells and Max Liboiron, as published by the Civic Laboratory for Environmental Action Research, August 2016.

Beaufort Number	Description	Wind speed	Wave height	Sea conditions	Land conditions	
0	Calm	< 1 knot < 1 mph < 2 km/h	0 ft 0 m	Sea like a mirror	Smoke rises vertically	
1	Light air	1–3 knots 1–3 mph 2–5 km/h	0–1 ft 0–0.3 m	Ripples	Direction shown by smoke drift	
2	Light breeze	4–6 knots 4–7 mph 6–11 km/h	1–2 ft 0.3–0.6 m	Small wavelets	Wind felt on face	
3	Gentle breeze	7–10 knots 8–12 mph 12–19 km/h	2–4 ft 0.6–1.2 m	Large wavelets	Leaves and small twigs in constant motion	
4	Moderate breeze	11–16 knots 13–18 mph 20–28 km/h	3.5–6 ft 1–2 m	Small waves	Raises dust and loose paper	
5	Fresh breeze	17–21 knots 19–24 mph 29–38 km/h	6–10 ft 2–3 m	Moderate waves	Small trees and leafs begin to sway	
6	Strong breeze	22–27 knots 25–31 mph 39–49 km/h	9–13 ft 3–4 m	Large waves	Large branches in motion	
7	High wind, moderate gale, near gale	28–33 knots 32–38 mph 50–61 km/h	13–19 ft 4–5.5 m	Sea heaps up	Whole trees in motion	
8	Gale, fresh gale	34–40 knots 39–46 mph 62–74 km/h	18–25 ft 5.5–7.5 m	Moderately high waves	Twigs break off trees	
9	Strong/severe gale	41–47 knots 47–54 mph 75–88 km/h	23–32 ft 7–10 m	High waves	Slight structural damage	
10	Storm, whole gale	48–55 knots 55–63 mph 89–102 km/h	29–41 ft 9–12.5 m	Very high waves	Trees uprooted, considerable structural damage	
11	Violent storm	56–63 knots 64–72 mph 103–117 km/h	37–52 ft 11.5–16 m	Exceptionally high waves	Widespread damage	
12	Hurricane force	≥ 64 knots ≥ 73 mph ≥ 118 km/h	≥ 46 ft ≥ 14 m	Exceptionally high waves, sea is completely white	Devastation	

Figure 13. Beaufort Sea state (from science-sparks.com).

2.2 Materials

Be sure to have these materials with you on the day of the trip:

a) The *LADI* herself
b) Cod End and extra cod end, if you have one
c) 3 x 20 m ropes (to attach the *LADI* to the stern of the boat and avoid the wake);
d) Extra hose clamps for the cod end
e) Nut driver
f) wrench
g) Extra rope for trawling
h) (optional) Glass or plastic sample jars (if you plan to do multiple trawls on your way out, bring more than you need)
i) (optional) Water squeeze-bottles to remove the plastics from the cod end on board. If you plan to do it back on port, water squeeze bottles are not necessary
j) 2x permanent markers
k) Logbook for data and a pencil (a waterproof notebook would be perfect)

l) Duct Tape
m) Rubber bands
n) Drinking water and food
o) Sunscreen and hat

2.3 Towing procedure: general information prior to sampling

a) The LADI trawl has wings so it can float unassisted. The use is weather dependent, as seen in section 2.1, and should be performed in Beaufort Sea state 0 to 3;
b) To attach the *LADI*, use two ropes: one rope attaches to the top-left eye at one end and the top-right eye at the other. The third rope attaches to the bottom eye, is tied to the middle of the upper rope, and extends onwards to be attached to the trawling ropes later (Figure 14).
c) Towing speed and time must be limited to avoid clogging the net; we suggest towing for 30 min at ~2 knots;
d) To have representative and quantitative data, at least 3 tows should be done in the same location;
e) The LADI should be deployed from the side of the boat and away from the engine to avoid the wake, because the disturbed water may drive plastics downward and below the net, giving an inaccurate sampling. When the *LADI* trawl is positioned behind the vessel, we recommend a distance behind between 15 and 20 m;
f) If the *LADI* is positioned behind the boat and at a distance between 15 and 20 m, remember to bring a day shape along to signal other seafarers that you have restricted maneuver and are towing an instrument.
g) We recommend collecting a blank sample from the equipment (without it having touched the water), as well as from the ropes, the boat and any plastic material that might be on board (a small fragment is sufficient).

Figure 14. How the LADI trawl is attached, from the original document (Coyle et al., 2016, the Civic Laboratory for Environmental Action Research).

2.4 Towing procedure: the sampling

After reaching your sampling location:

a) Set up the arm and trawling ropes so *LADI* will be on the side of the boat, or alternatively behind distant enough to not be disturbed and not in the wake;
b) Before each trawl, make sure there are two or three hose clamps attaching the net and the cod end and that they are very tight, or you may risk to lose the cod end at sea;
c) Do a short 'practice run' to flush the net, and to make sure *LADI* is well positioned at speed;
d) Adjust the ropes or arm if necessary;
e) Record latitude and longitude just before deployment;
f) Start your tracker app just before deployment;
g) Record the time just before deployment;
h) Lower the trawl into the water on the side of the boat, making sure to drop it upright
i) Pull the trawl by maintaining a consistent speed of about 2-3 knots with in a straight course for at least 30 minutes, but if you notice the cod end is filling up quickly, try to end before the net gets clogged;
j) When you have finished your trawl (after 30 min), stop the tracker app, stop the boat, record the time and pull the trawl out of the water. Record latitude and longitude;
k) If doing multiple tows, collect the sample from the cod end into one sample glass or plastic jar with the help of a water squeeze bottle, and thoroughly wash out the entire net and cod end for the successive deployment;
l) If doing multiple tows, trawl in both or multiple directions to cover a representative area.

2.5 Sampling Log and how to calculate the amount of plastic per surface area (m^2)

A sampling log can be created from the attached Appendix 4, or the required information can be recorded in a logbook (notebook). Here's an example:

date	trawl nr.	start tow (time, local)	Lat (start)	Long (start)	speed (kn) from GPS	speed (m/s) from GPS	Beaufort	end tow (time, local)	number of minutes	Lat (end)	Long (end)	notes	nr. of plastics

Where Lat and Long = Latitude and Longitude, the start and end tow times are the time the trawling will start and end. It is important to add any additional note of something of interest you may record during your sampling. The last column, nr. of plastics, will be filled in once back on land (or in the lab).

Because many microplastics float on the top of the sea surface, once you have the total number of plastics found in each trawl, you can calculate the number of plastics per surface area (m^2) instead of volume:

$$\frac{\text{nr. of plastics found}}{(distance\ travelled) * (mouth\ width)}$$

The distance travelled and the mouth width are both in meters (m). If you perform multiple trawls per each sampling, then the nr. of plastics per surface area should be calculated as an average of the *n* samplings.

3. Back on land: how to categorize plastic marine debris

3.1 Materials

Once back on land with the logbook filled in about your samplings, you will need the following materials:

a) Tweezers (at least 3, depending on the number of participants)
b) Water squeeze bottle filled with tap water (1 or 2)
c) A ruler to measure plastic debris
d) A color chart (Appendix C)
e) Paper towels to dry the samples
f) A rectangular plastic box big enough where you can empty the cod end or the sample bottle
g) Fine permanent markers (2 or 3)
h) Plastic tubes (2 mL volume) where you will place the samples (ideally, one plastic particle per tube)
i) A metadata sheet, paper and pencils

3.2 Procedure

Be careful not to introduce any external contamination in the form of plastic fragments that do not belong to your sample.

Pour the sample from the cod end into the plastic box flushing the cod end with enough fresh water to remove all the particles, or, if you have performed this procedure on board and already emptied the cod end into a sampling bottle, pour the sample to start the visual inspection.

Count the plastic fragments and write this number in the sampling log (see section 2.5) to calculate the number of plastics per surface area.

Subsequently, assign a number to each plastic fragment and number the plastic tubes of 2 mL volume accordingly (e.g., 20 fragments = 20 tubes).

Note down the size, type, shape, color of each fragment. Record any additional information that you think is useful (e.g. recent fragment, or very much weathered, covered with organic life or biofilm, etc..and anything curious you may notice, like the brand if visible, or if you think it comes from a plastic cap, bottle or other recognizable material).

After writing down all the information, dry the fragments as much as possible with some paper towel and place each single plastic fragment in the respective numbered collection tube of 2 mL volume and close the cap.

Send the numbered tubes, the sampling log and the metadata sheet to the lab that will confirm if the fragments found are plastic and in case, what polymer type.

3.3 Filling in the metadata sheet

A. Describing the size: measure the size of the longer side in mm (with the ruler)

B. Describing the type (Figure 15)
    a. Fragment
    b. Pellet
    c. Film

d. Foam
e. Line / Thread / Fibre

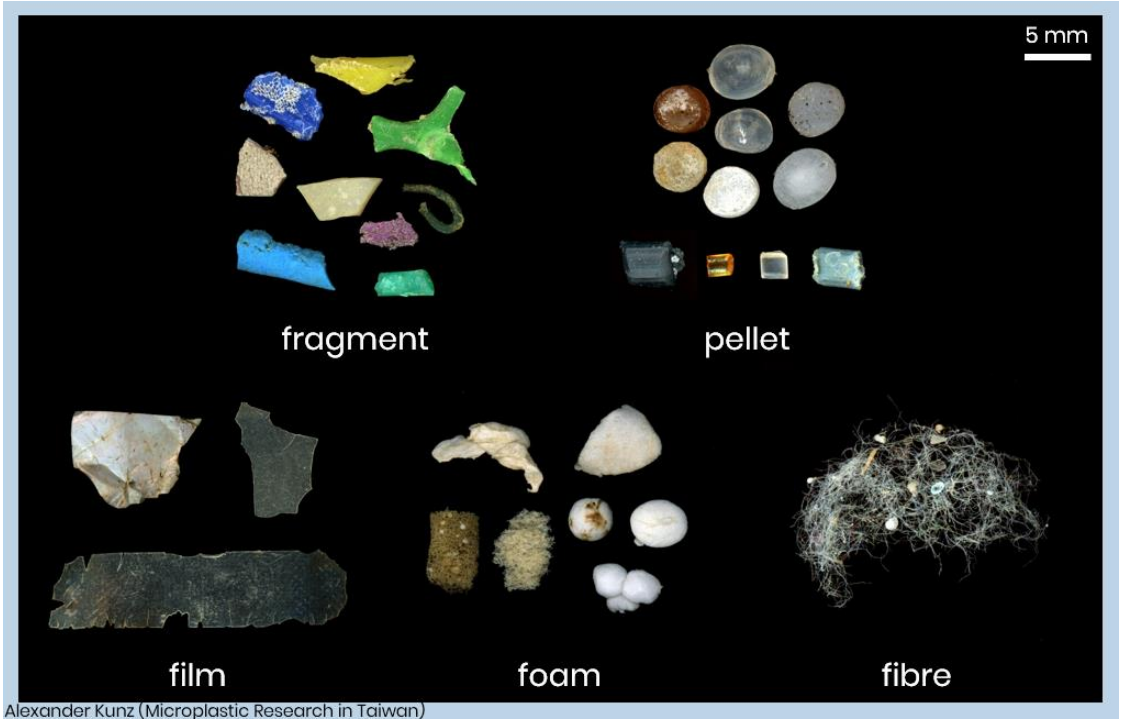

Figure 15. The types of plastic fragments (from https://microplasticresearch.wordpress.com/what-is-microplastic/, Dr. Alexander Kunz).

C. Describing the shape (Figure 16)
   a. Angular
   b. Sub-angular
   c. Sub-rounded
   d. Rounded

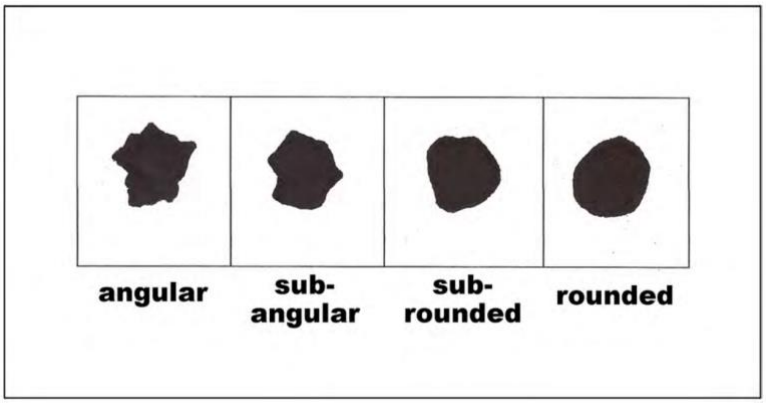

Figure 16. The shape of plastic fragments, from the original document (Coyle et al., 2016, the Civic Laboratory for Environmental Action Research).

D. Describing the color: use the color palette in Appendix to individuate the color of the fragments.

4. Appendix A – Sampling log

date	trawl nr.	start tow (time, local)	Lat (start)	Long (start)	speed (kn) from GPS	speed (m/s) from GPS	Beaufort	end tow (time, local)	number of minutes	Lat (end)	Long (end)	notes	microplastics nr.

5. Appendix B - metadata sheet

date	nr.	N°tube	shape/type (eg. fragment/film)	size (mm)	color	Lat (N).	Long (E).	Notes

6. Appendix C – color palette