

A detailed underwater and on-board workflow for marine ecological research, using a subtidal kelp forest study

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Table S1. A detailed description of the materials used in the study.

Material	Detailed description
Acrylic boards	This material is suitable for annotations under wet conditions, including underwater. Large acrylic plates (1.2m x 1.8m) were cut into smaller sections with a sharp cutter. Depending on the requirements for their use, the boards were cut into different sizes; for annotation at the surface, 30cm x 22cm sections were prepared, while for underwater work smaller 22cm x 15cm boards were prepared, to make them more ergonomic and to optimize use of space. Sandpaper was used to scrape the surface of the boards and make them abrasive enough to write on with an ordinary graphite pencil. Small holes were drilled close to one of the corners, to insert steel rings for facilitating attachment to the D-rings on the harness/BCD (buoyancy control device), using double-ended bolt snap hooks. When underwater, pencils are easily lost or broken. To avoid this, use of latex tubes and small cable ties is recommended for securing pencils and keeping them safe when not in use (Fig. 2).
Dismountable circumference	To form a 2m ² circumference, 5m of gas hose was used (bright orange color). Nipples were screwed in at both ends to enable easy mounting/dismounting underwater. Filling the hose with sand is recommended to avoid positive buoyancy.
Transect	A 20m-long transect line consisting of a 3/8" white polypropylene halyard marked with knots indicating 1m intervals and knots-and-lead indicating 2m intervals.
Quadrats	Stainless steel 9mm (3/8") were used, as specified by Moreno (2020).
Modified axe ("barreta")	The "barreta" was manufactured in the town of San Juan de Marcona (province of Nasca, Peru). This tool is used to cut the perimeter of the holdfast and then lever up to detach the sporophyte from the substrate (see Fig. S3-D and "Underwater workflow for marine ecological research" - https://youtu.be/zzhOBGybP_A). The barreta is indispensable when cutting robust (coalescent) holdfasts, particularly in areas highly exposed to waves and strong currents. In contrast, when sampling in sheltered areas holdfasts can be removed manually with ease ("Manual extraction of <i>Lessonia trabeculata</i> holdfast" - https://www.youtube.com/watch?v=PrI0yYBaD8w).

Table S2. Details of the software, materials and equipment, including a brief description, dimensions, costs and links.

Item	Description	Weight (kg)	Length x width (cm)	Cost (PEN USD)	Availability
Acrylic cutter	To cut the acrylic plates	standard	standard	15 3.75	Hardware store
Acrylic plate	The cost represents the whole plate (180cm x 120cm). However, this had to be cut into smaller plates of 22cm x 15cm (indicated weight corresponds to this size)	0.05	22 x 15	100 25	Av. Tomás Marsano (Lima, Peru)
CastAway-CTD	Lightweight, easy to use instrument designed for quick and accurate conductivity, temperature and depth profiles	0.45	20.2 x 7.2	30,669 7,667	https://www.sontek.com/castaway-ctd
Dismountable circumference (without sand fill)	Made of GLP 3/8" hose (max. pressure: 10 bar) with nipples at the end for enclosure and leads	1	500	20 5	Hardware store (Av. Angamos Este 1184, Surquillo, Lima)
Double-ended (double-eye) bolt snaps	4" made of stainless steel	0.1	10	20 5	https://www.divegearexpress.com/
GoPro Hero 7 Black edition	Action camera with Full HD video capacity	0.116	6.2 x 4.5 x 3.3	1500 375	https://www.gopro.pe
GoPro SuperSuit	GoPro underwater housing for depths <30m	0.09	8.3 x 8.1 x 5.7	170 42.5	https://gopro.com/en/us/shop/mounts-accessories/super-suit/AADIV-001.html
HawkEye DepthTrax	Easily deployed handheld depth sounder	0.3	20 x 4.5	300 75	https://hawkeyelectronics.com/collections/handheld-depth-finders-and-sounders
Macro lens for GoPro	+15 MacroMate Mini Underwater Macro Lens	0.2	7 x 7	480 120	https://www.backscatter.com/15-MacroMate-Mini-Underwater-Macro-Lens-for-GoPro-3-3-4-5-6-7-8-9

Modified axe "barreta"	Made of metal	1.1	49 x 14 (blade: 16 x 7)	70 17.5	Marcona, Ica (RUC: 10448874392)
MSW Pro	Magicseaweed 12-month subscription	-	-	108 27	https://magicseaweed.com/
Prepared 20m transect line	(1/4" polypropylene halyard + knots and leads)	1.5	2000	50 12.5	Hardware store
SOLA 2500 video lights	Backscatter Sola 2500 Dual Video Light Package	1	10.5 x 5.2	3080 770	https://www.backscatter.com/Backscatter-Sola-2500-Dual-Video-Flood-Light-Package
SS* keyrings	To enable easy attachment of the acrylic plates to BCD	-	Ø: 2.5	7 1.75	Maritime store
SS* quadrats	Internal 50cm x 50cm including a 25cm x 25cm	1.35	50 each side	190 48	Aceros Ventas y Servicios S.A.C. (Av. Argentina 751, Lima 15079)
Suunto Vyper Novo Dive Computer	RGBM algorithm. Nitrox-capable dive computer for advanced divers with optional air integration. Digital compass and gas switching. USB cable to download the dive profiles	0.134	7.12 x 7.12 x 2.95	1400 350	https://www.suunto.com/en-gb/Products/dive-computers-and-instruments/Suunto-Vyper-Novo/suunto-vyper-novo-graphite2/
Suunto DM5	Suunto software	-	-	Free to download	https://www.suunto.com/en-gb/Support/software-support/dm5/

*SS: stainless steel. 1USD=4PEN. Cost in bold type indicates the currency used to pay for the item

Table S3. Factors affecting human performance identified in the study. Adapted from Sandal et al. (2006).

ICE factors and variables	Factors identified in this study
Physical conditions (temperature, tidal surges, radiation exposure, pressure)	• Exposure to cold (especially for divers, water 13°C).
	• Hyperbaric environment.
	• Perturbation of tides and strong currents near shore.
	• Strong winds (up to 40 km.h-1).
Habitability and life support (facilities and supplies for crew members)	• Low to mid radiation exposure.
	• Vessel of 3.8 gross tonnage as habitat in continual pendular movement.
	• Reduced resting space.
	• Autonomous (scuba) and semi-autonomous (hookah, surface supply Sfs) diving systems.
Crew attributes	• Limited supplies for work.
	• First aid kit available.
	• Crew number.
	• Knowledge of operating and maintaining the vessel.
Operational attributes (tasks, workload, hazards, communications)	• Knowledge of what constitutes health and nutrition.
	• Previous experience in similar subtidal surveys.
	• Calmness and focus during emergencies, despite fatigue.
	• Work in a semi-confined space, small vessel.
	• Risk while navigating near rocky shores.
	• Extra-vehicular activities, diving operations in strong currents.
• On-site data and sample acquisition.	
• Study area isolated from population centers.	
• Difficult, delayed evacuation.	



Table S4. Project titles and information on the undergraduate thesis projects derived from this sampling initiative – Universidad Científica del Sur.

Framework Project		
"Determinación de la distribución, la biomasa e importancia ecológica del 'aracanto palo' <i>Lessonia trabeculata</i> en el ámbito marino de la Reserva Nacional San Fernando" [Beca SERNANP 2020 – A1 Equipo IMP-05]		
Registration code N° 010-2021-PRO99		
Thesis project title- registration code	Student	Directorial Resolution (RD); date of approval
"Estimación de la biomasa de <i>Lessonia trabeculata</i> 'aracanto palo' (<i>Lessoniaceae</i>) dentro del ámbito submareal de la RNSF" – N°184-2021-PRE5	Bruno Cevallos Gil	N°057-DACBM-DAFCVB-U; 07/05/2021
"Evaluación de los ensambles de macroalgas asociadas al 'aracanto palo' <i>Lessonia trabeculata</i> dentro del ámbito submareal de la Reserva Nacional San Fernando" – N°251-2021-PRE5	Rodrigo Gómez Sánchez Huaco	N°087-DACBM-DAFCVB-U; 13/07/2021
"Epibiontes y otra fauna asociada al "aracanto palo" <i>Lessonia trabeculate</i> dentro del ámbito submareal de la RNSF" – N°343-2021-PRE5	Rubén Alejandro Torrejón Zegarra	05/10/2021