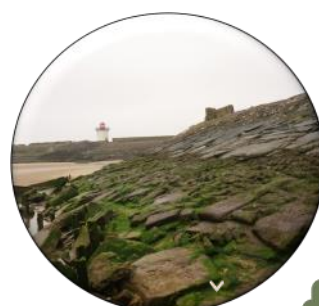


Ecosystem Functions and Services Habitat Case Studies



The EFPREDICT tool has been developed by Dr. Tom Fairchild and Dr. John Griffin of Swansea University to predict ecosystem functional rates and service indicators, as part of the Ecostructure Project. More information on the Ecostructure project can be found at <https://www.ecostructureproject.eu/>.

Ecostructure is part-funded by the European Regional Development Fund (ERDF) through the Ireland-Wales Cooperation Programme 2014-2020

ES1.4.0 2021



Ecosystem Functions and Services Summary

Ecosystem functions and services are key drivers of the health of ecosystems and human benefits provided by the ecological communities that live there. It is increasingly becoming recognised that integrating the functions and services into environmental management frameworks is important for the long term viability of natural systems, rather than simply having biodiversity targets in isolation. One major challenge of integrating ecosystem functions and services into planning and policy processes is the lack of information about how species and whole communities can feed in to providing multiple functions and services, and this lack of information is particularly acute in the marine environment, where little data on functioning exists.

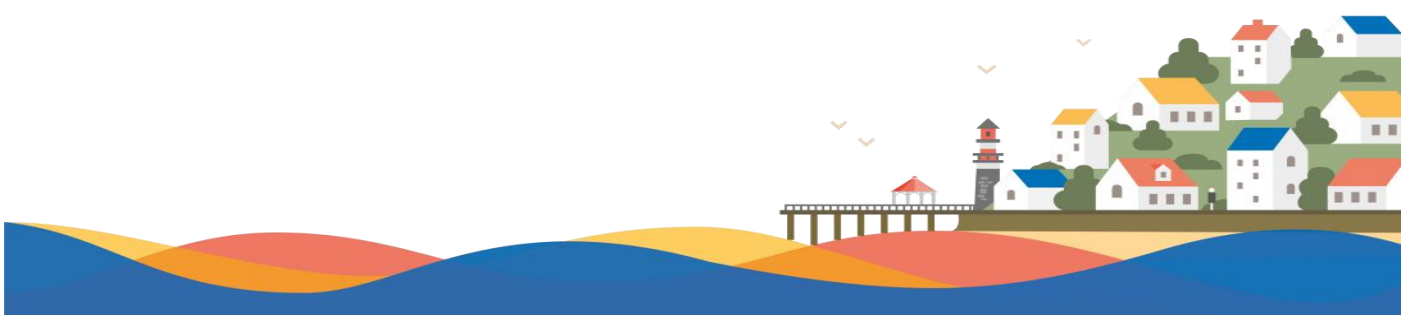
Modelling tools, including the EFPREDICT tool presented here, provide a way to extrapolate our limited knowledge of species to those where data is not available using species trait based models, and can allow us to understand the world around us and make predictions for new, novel habitats or environmental conditions. Our modelling case study scenarios for intertidal coastlines, based on real surveyed locations, demonstrate the importance of promoting complex, mature coastal communities through naturalistic shoreline design, and how this can contribute to healthy, resilient ecosystems across seasons.

Main findings

- Communities that have greater abundances of larger, long lived species have lower peak functional rates during the summer, but exhibit greater seasonal stability than those with large abundances of ephemeral species. This is due to longer lived species persisting through the winter, while ephemeral or short-lived species—which often have slightly higher summer peak functional rates due to their opportunistic nature—typically die back substantially over winter.
- Of these long lived species, canopy forming organisms, such as *Fucus spp.* can dominate functions; either through accumulating substantial biomass which uptakes nutrients and provides oxygenation via photosynthesis, or by facilitating diverse communities of understory species and epibionts which can contribute substantially to individual functions and multifunctionality of the system.
- These diverse, long lived communities are far more likely to be found on natural rocky shores rather than artificial shores which typically have higher proportions of opportunistic ephemeral species, as natural shores tend to be more physically complex, and provide greater opportunities for species to establish and survive.
- As a result, natural shores with long-lived species are likely to have greater year-round functional rates, and have far higher winter functional rates. This can be important as increased precipitation and surface run-off often leads to poorer water quality over winter, which can be somewhat mitigated by communities which perform functions well over the winter.
- Furthermore, communities on naturalistic shores tend to be greatly preferred aesthetically by humans compared to artificial analogues due to their greater diversity and a preference for less obviously artificial underlying structures.

Take home message

- As well as pure biodiversity benefits, enhancing artificial structures to mimic natural shorelines is likely to provide more stable ecosystem functioning and services across seasons and enhance overall multifunctionality (by promoting the growth of larger long-lived species), even if peak summer rates for metabolic functions are traded off.



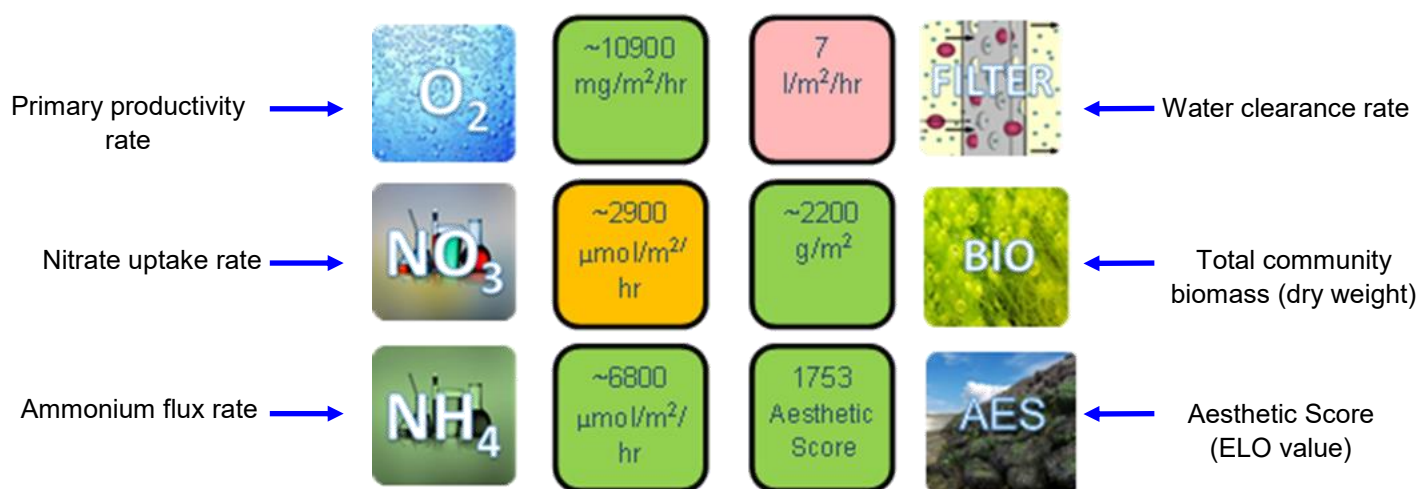
Ecosystem Functions and Services

How To Understand this document

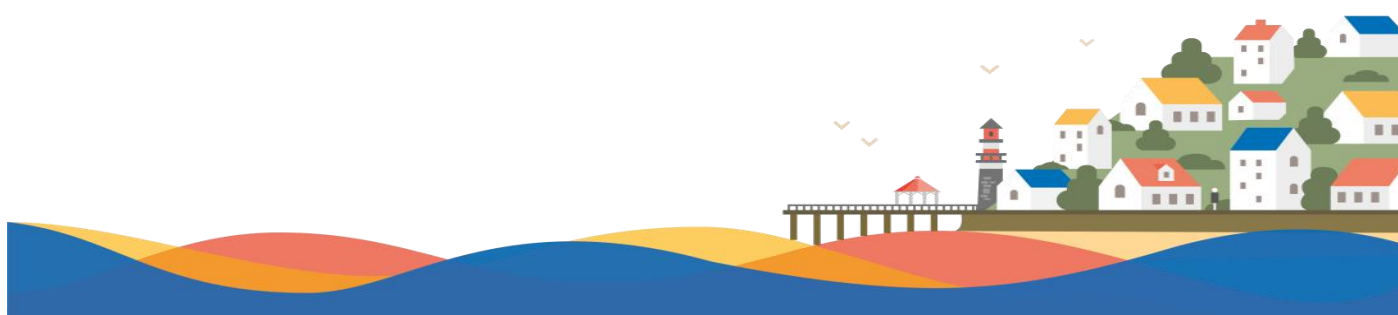
This document summarises the main differences between different community types growing on natural and artificial structures, and how these communities can function very differently depending on the substrate, and the season on which we consider them. The results presented in these case-studies have been derived from community surveys combined with a predictive trait-based model to understand the effects that ecological communities can have on a range of key ecosystem functions and service indicators. This work has been done as part of the Ecostructure project looking at climate change adaption through ecologically sensitive coastal engineering. More information on the Ecostructure project can be found [here](#).

On the following pages, you will find case-studies for a range of common intertidal community types, and how the ecosystem functions and service indicators for them vary. For each case-study community, a summary page is provided, and details the relevance and distribution of each community type, individual functional rates and fluxes for communities across seasons, and a comparison highlighting how natural shores and artificial analogues can perform functions differently. Functional rates are displayed in functional matrixes (below) comparing summer and winter rates for natural shore, and summer peak functional rates for artificial shores. For each community type, there is also a comparison figure, illustrating the percentage over-winter reduction in functional rates compared with the summer.

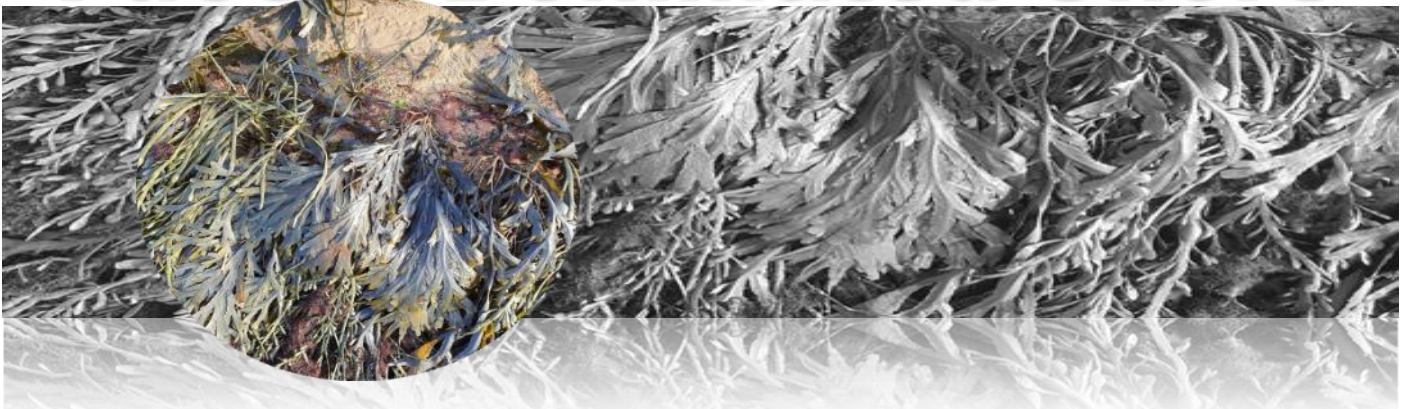
Typical Summer Community



The functional matrixes provide an overview of rates of primary productivity, nitrate uptake, ammonium flux, water clearance rate, total dry biomass and aesthetic value. Each parameter is “traffic light” colour coded indicating high (Green), medium (Orange) and low (Red) functional rates.



Ecosystem Functions and Services Furoid Dominated Shore

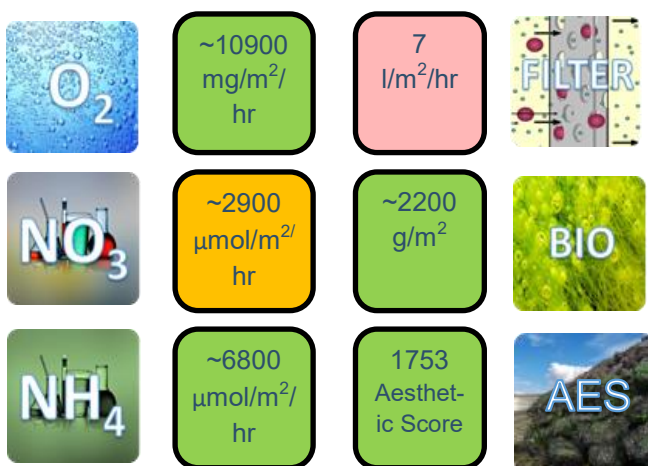


Furoid dominated shore with a mix of *Fucus* species, *Ascophyllum nodulosum* and *Pelvitia caniculata*, overlaying a diverse understory community of smaller seaweed species such as *Cladophora rupestris*, *Palmaria palmata* and *Plocamium* spp. on natural shores. A variety of snail, limpet and barnacle species are also frequently present among the seaweeds. This habitat type is common in the mid-intertidal of natural rocky shores, as well as on sea defence structures, although these tend to host lower furoid biomass but greater biomass of ephemeral taxa, such as *Ulva* spp..

These habitats can provide important ecosystem functions and processes, supporting high levels of primary productivity and taking up nutrients quickly, particularly because of the high algal biomass they support. This helps to maintain healthy ecosystems by providing good water quality across seasons, and can prevent eutrophication events in areas with high nutrient concentrations by removing nitrate and ammonium sources that can cause algal blooms. However, typically low numbers of filter feeding animals make them less able to remove phytoplankton and particulates in the water.

These habitats, particularly those growing on natural shores, also tend to support high levels of biodiversity and create large biomass stocks which can be further utilised by smaller animals - and seaweed species - as sources of food and shelter, and can form the basis for important food chains. This diversity and ability to completely cover shore structures also makes them particularly culturally valuable along natural coasts, providing aesthetic appeal, calming spaces and interest potential: supporting educational, recreational and wellbeing services.

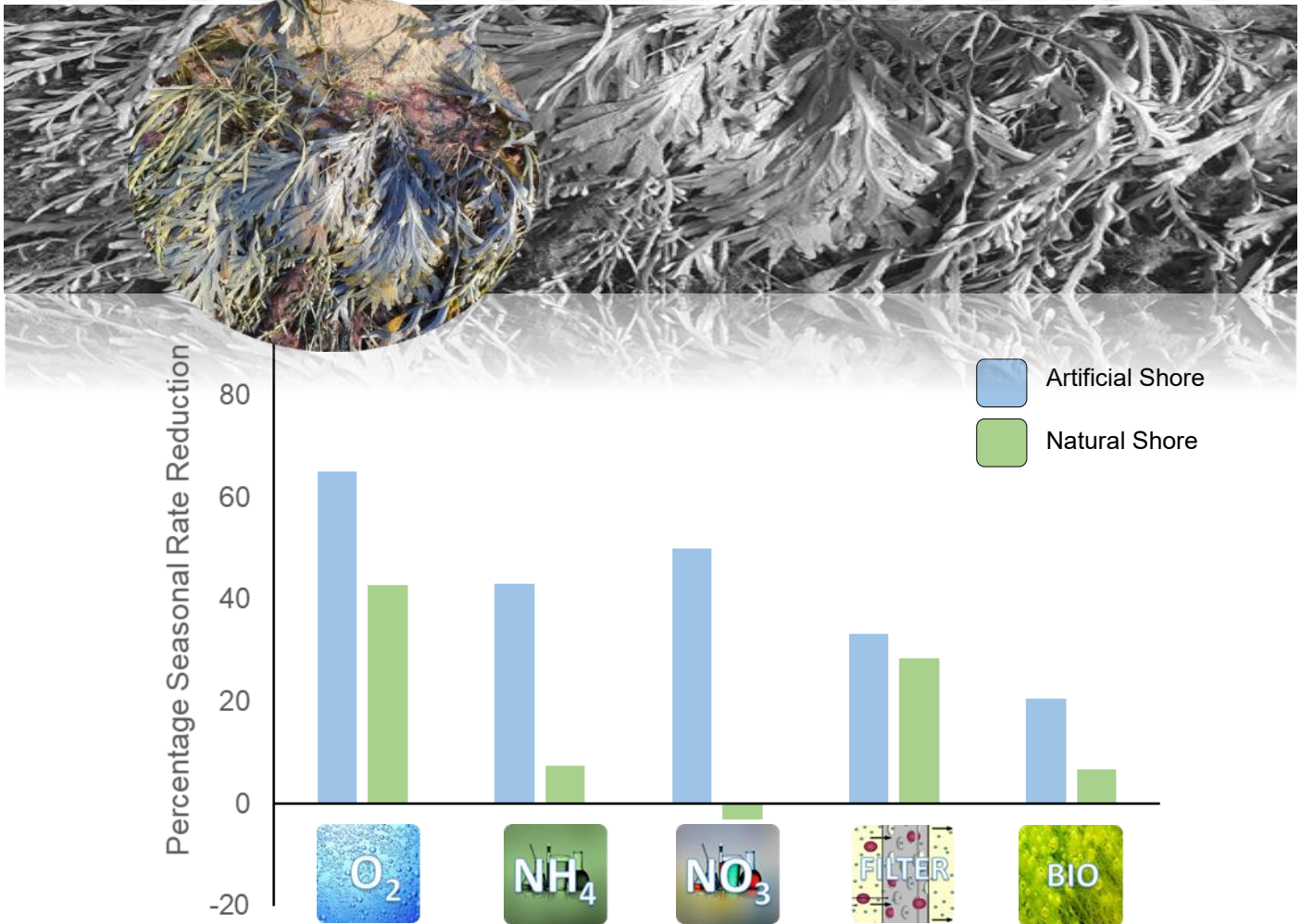
Typical Summer Community



Typical Winter Community

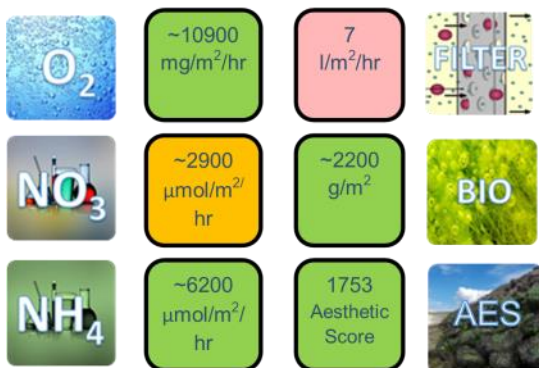


Ecosystem Functions and Services Furoid Dominated Shore



Fucus dominated shores show lower seasonal variability in key metabolic ecosystem functions than many other community types as dominant fucoids persist with only modest die back during the winter months. During the summer, productivity and nutrient cycling rates are very high, and may be higher still on artificial structures due to greater abundances of ephemeral species. However, as communities on artificial structures (blue) typically contain larger proportions of ephemeral species than their natural analogues (green), they are more likely to have greater seasonal reductions in metabolic functional rates during the winter as a result (~50-60%). Interestingly there is indications that winter nitrate uptake rates may exceed summer uptake rates on natural shores as increases in winter nitrate water concentrations can enhance uptake rates in fucoids despite lower temperatures depressing uptake kinetics.

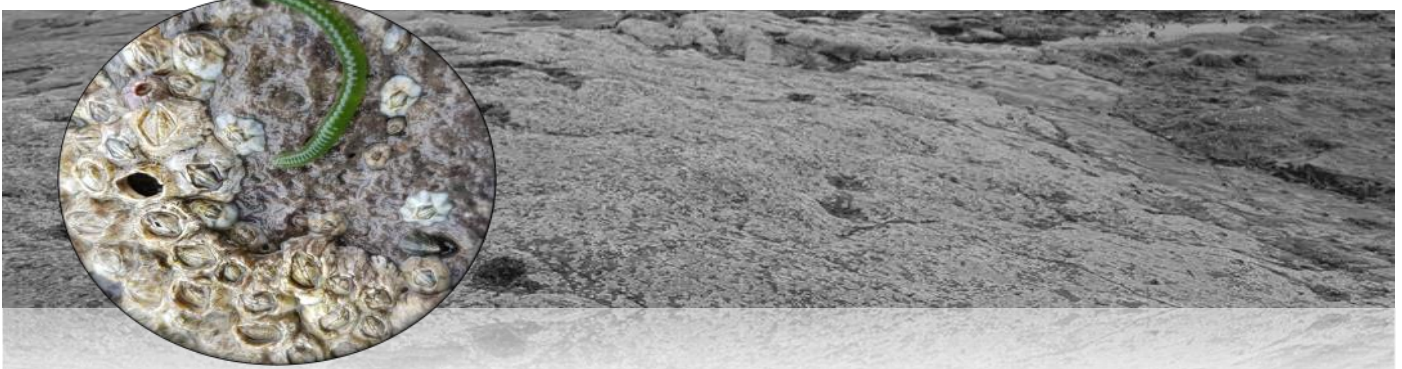
Typical Natural Shore (Summer)



Typical Artificial Shore (Summer)



Ecosystem Functions and Services Barnacle Dominated Shore



Barnacle dominated shore with a mix of Limpet species, grazing gastropods and *Ulva spp.*, as well as less common ephemeral seaweed species such as *Cladophora rupestris*, *Porphyra spp.*, sparse fucus stands and occasional worms (such as *Eulalia spp.*). This habitat type is common in the mid-high intertidal of natural rocky shores, particularly at exposed sites, as well as often dominating coastal defence structures.

These habitats often provide limited ecosystem functions and processes, supporting low levels of primary productivity and taking up nutrients poorly due to animal dominance and low algal biomass. Furthermore, the abundance of ephemeral species that also inhabit these habitats leads to substantial seasonal variation in primary productivity and nutrient uptake rates, with winter rates much lower due to extensive die off. Despite the large abundances of filter feeding barnacles clearance rates also tend to be low, making these communities poor at removing phytoplankton and particulates in the water and subsequently less able to maintain or improve water quality.

Barnacle dominated shores on natural shores can be quite diverse, but also tend to contain low animal and algal biomass. This perceivable diversity but strong species dominance makes them moderately attractive to local human communities and visitors, providing some aesthetic appeal, calming spaces and interest potential, yet may also provide hazards to coastal access.

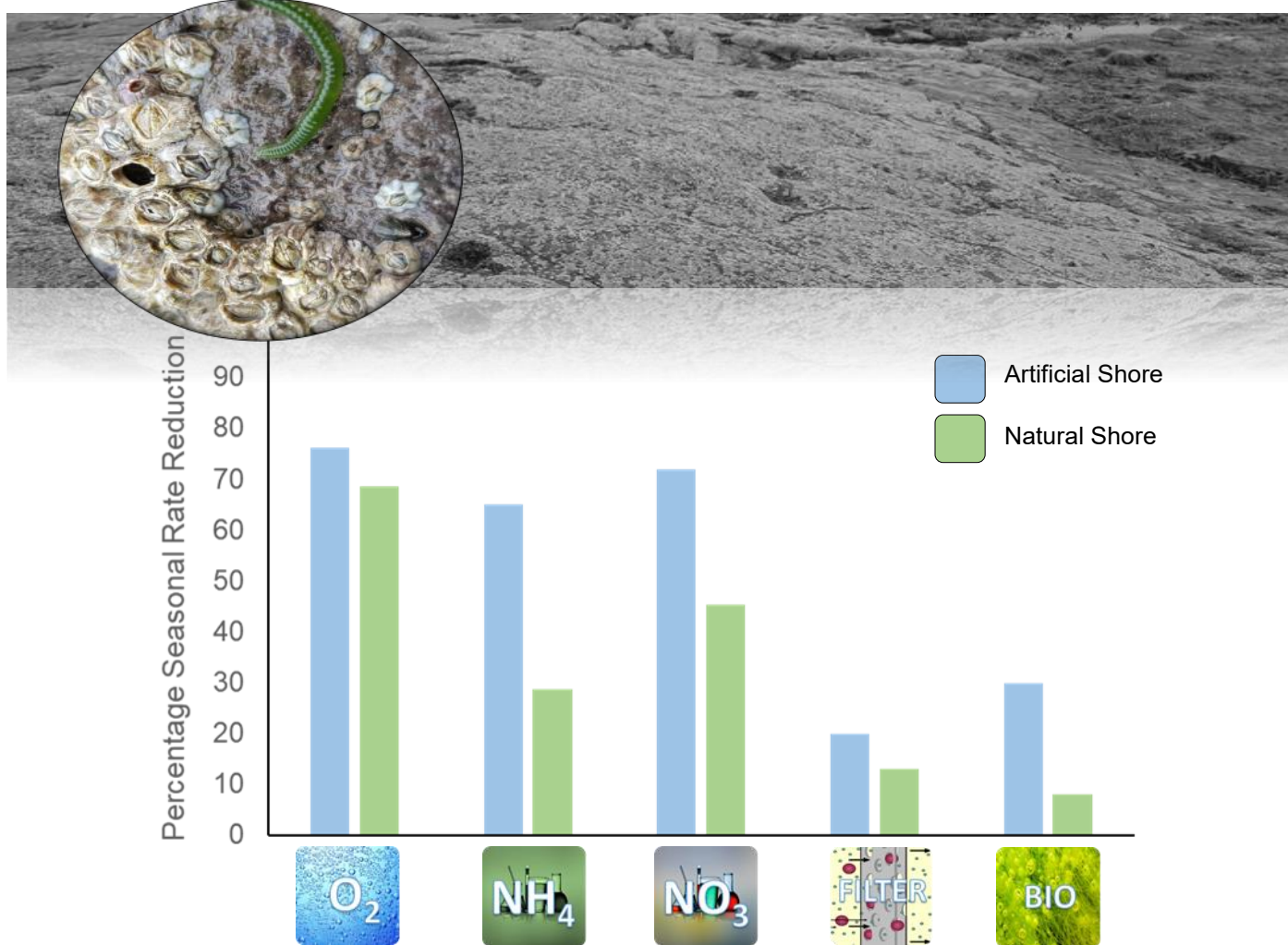
Typical Summer Community



Typical Winter Community

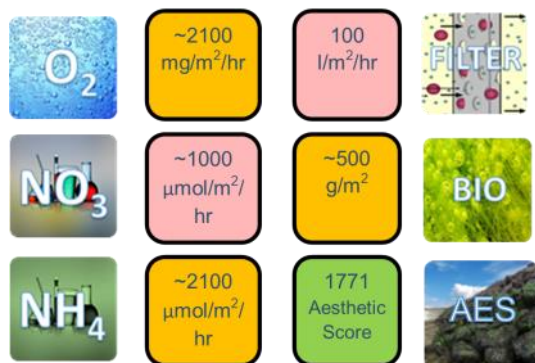


Ecosystem Functions and Services Barnacle Dominated Shore



Barnacle dominated shores show large seasonal variability in key metabolic ecosystem functions due to hi proportions of ephemeral algal species, which often die back during the winter months. During the summer, productivity and nutrient cycling rates are generally low, but may be higher on artificial structures due to larger abundances of ephemeral species. However, as communities on artificial structures (blue) typically contain larger proportions of ephemeral species which are reduced over winter compared to their natural analogues (green), they are more likely to have greater seasonal reductions in metabolic functional rates during the winter as a result (~65-75%).

Typical Natural Shore (Summer)



Typical Artificial Shore (Summer)



Ecosystem Functions and Services Mussel Dominated Shore

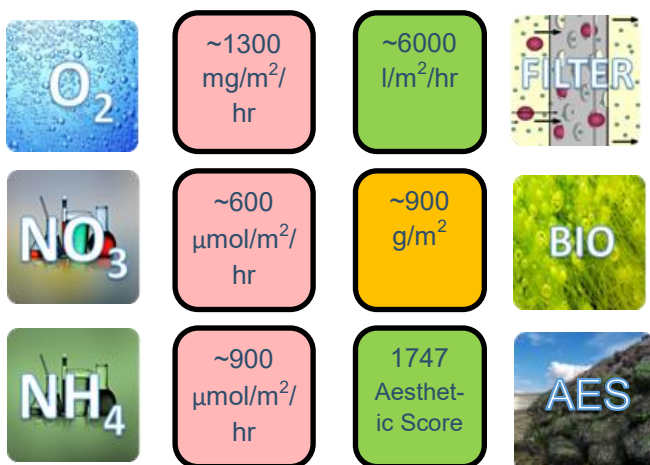


Mussel dominated shore with extensive *Mytilus edulis* patches, sparse fucoid stands, occasional ephemeral red and green seaweeds and a variety of grazing and predatory gastropods, hydroids and sponge species. These habitats can form extensive mussel reefs along natural shores, or alternatively can occupy cracks and fissures in rock along both natural and artificial coastal areas.

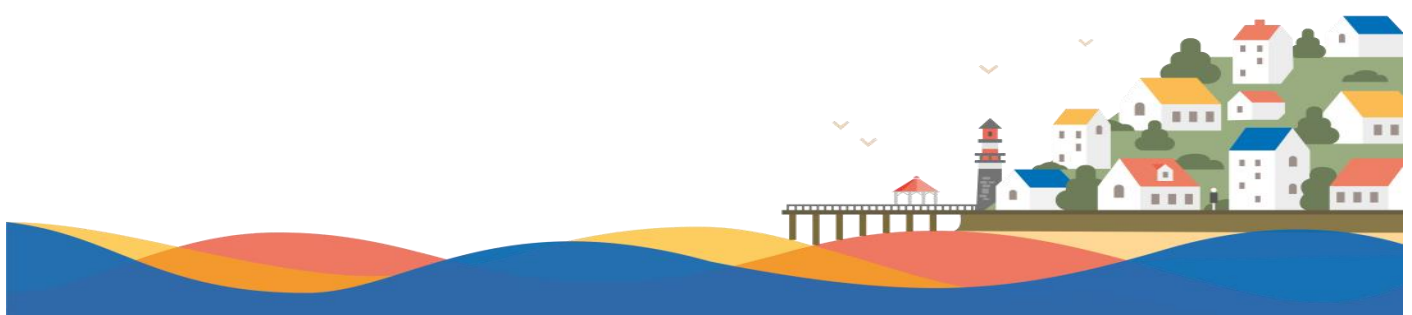
The dominance of space-filling mussels typically mean these habitats have moderate to low productivity and nutrient uptake rates, but can exhibit high water clearance rates through large filter-feeding organism biomass., particularly along natural shorelines. This can help remove particulates from the water, and contribute to maintaining good water quality. Along artificial structures, mussel aggregations tend to be less dense and an increase in ephemeral species such as *Ulva lactuca* can enhance productivity and nutrient cycling rates, trading off at the expense of filtration rates.

These habitats can be quite diverse as the mussels can act as foundation species for a variety of seaweeds and animals, particularly along natural coastlines. This diversity can enhance the local aesthetics of the shore, and aesthetic appreciation can be high, although this may be somewhat muted along artificial structures due to lower diversity communities and artificial structures being generally found to have lower baseline aesthetic values.

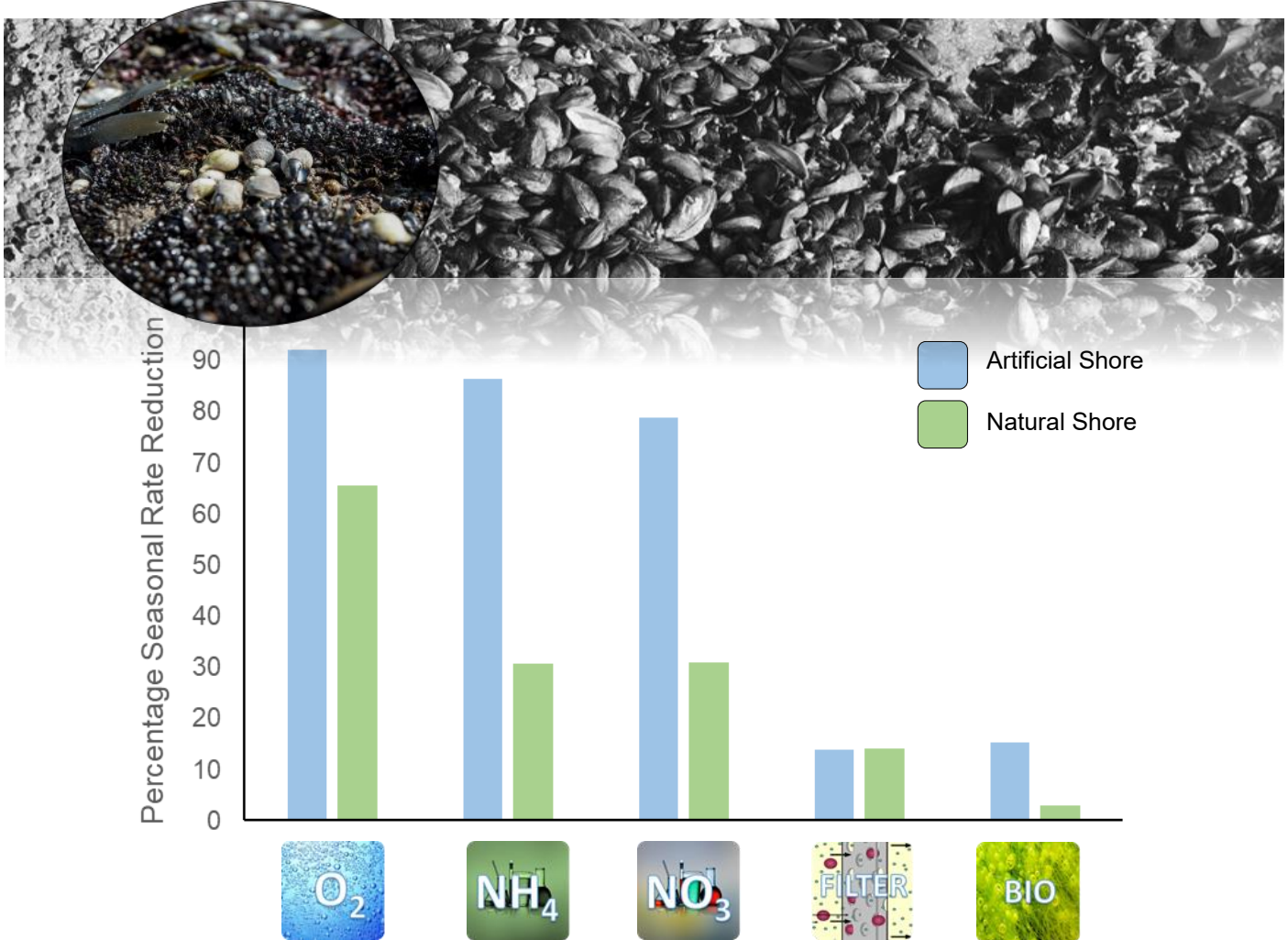
Typical Summer Community



Typical Winter Community

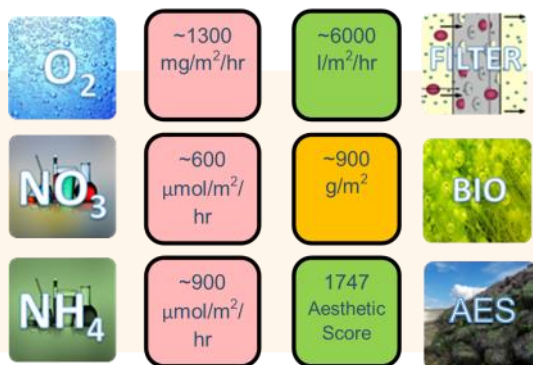


Ecosystem Functions and Services Mussel Dominated Shore

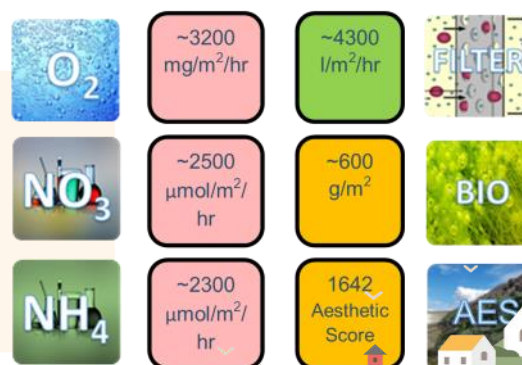


Mussel dominated shores show large seasonal variability in key metabolic ecosystem functions due to large biomasses of ephemeral algae species, which often die back during the winter months. During the summer, productivity and nutrient cycling rates are moderate, and may be higher on artificial structures due to large abundances of ephemeral species. However, as communities on artificial structures (blue) typically contain larger proportions of ephemeral species than their natural analogues (green), they are more likely to have greater seasonal reductions in metabolic functional rates during the winter as a result (~79-92%).

Typical Natural Shore (Summer)



Typical Artificial Shore (Summer)



Ecosystem Functions and Services

Ephemeral Dominated Shore

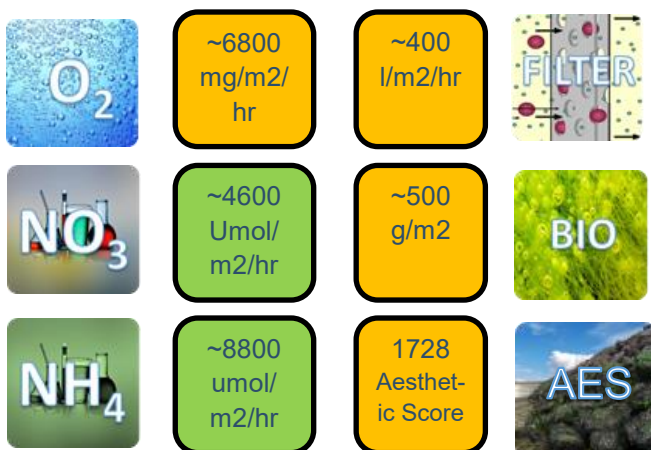


Ephemeral dominated shores typically consist of fast-growing annuals such as *Ulva spp.*, *Porphyra spp.*, *Cladophora* and *Ceramium* species, as well as other turf-forming filamentous species during the summer, but reduce in abundance significantly over the winter months. They also tend to host smaller grazers like *Rissoa* and littorinid snails which feed on the ephemeral algae. These communities are often found on frequently disturbed shores, where excess water nutrients can lead to dominance of fast-growing species, or along modern coastal defences where habitat is less suitable for larger species of seaweed to attach.

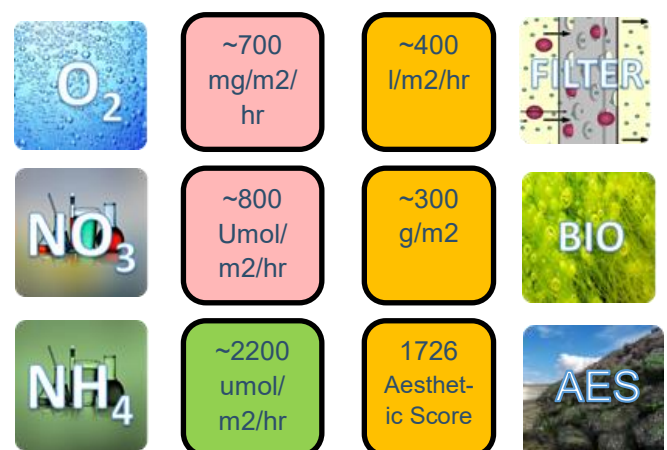
The opportunistic nature of ephemeral species means they are able to rapidly uptake ammonium, and particularly nitrate, from the water, and also often have high productivity values per unit mass during the summer months. However, these habitats also accumulate far less biomass, and are more seasonally transient than shores with larger slow growing seaweeds, which make them less effective at cycling nutrients and producing oxygen in the winter than communities such as fucus which persist year-round. Ephemeral dominated natural shores, however, often host mussel populations along cracks and fissures in the rock and can provide moderate water filtration rates year round.

These communities are often less diverse than other typical communities, and as such tend to be less culturally valuable than other communities, and negative perceptions of green and red ephemerals can lead to poor aesthetic appraisals by humans.

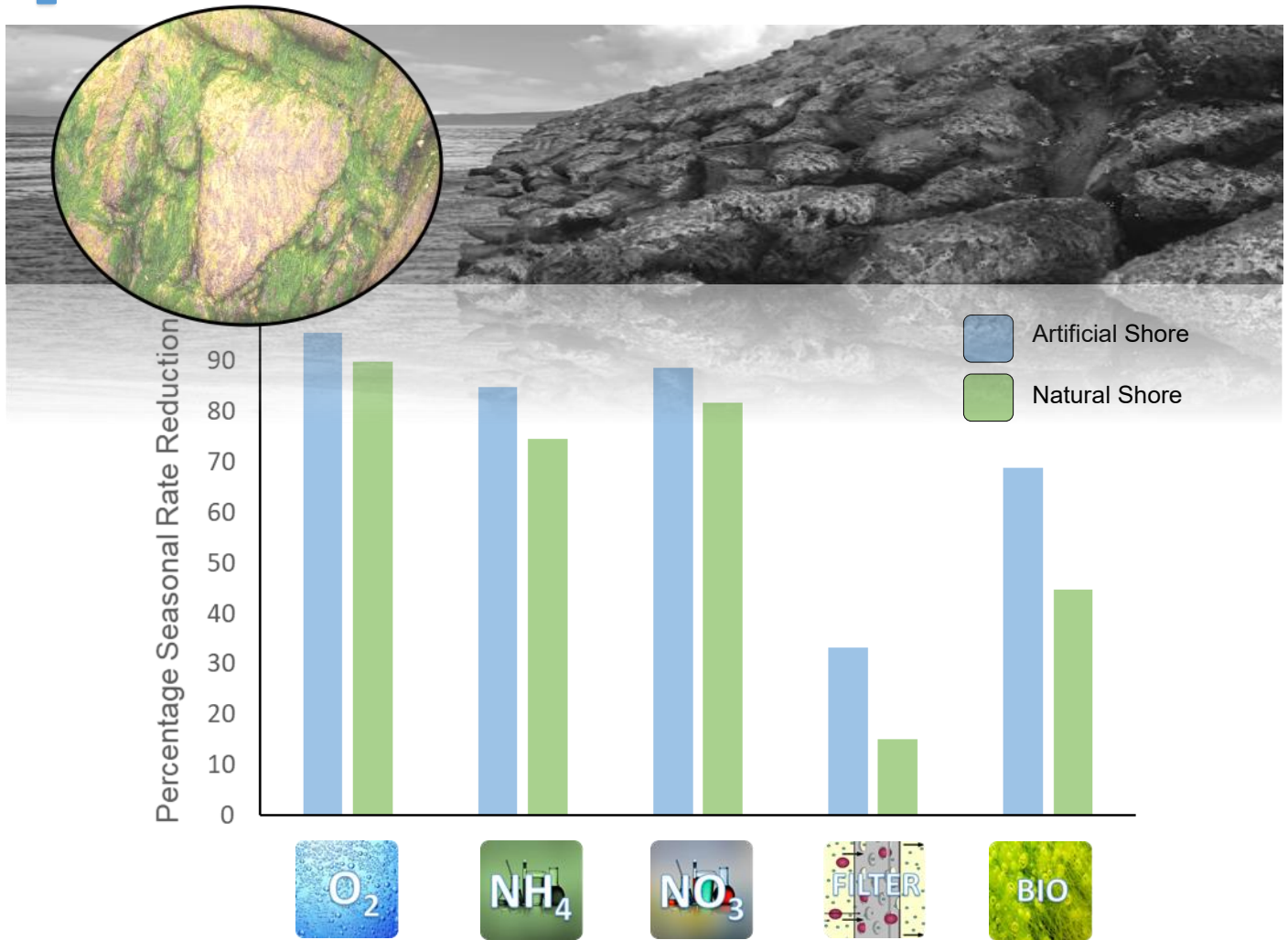
Typical Summer Community



Typical Winter Community

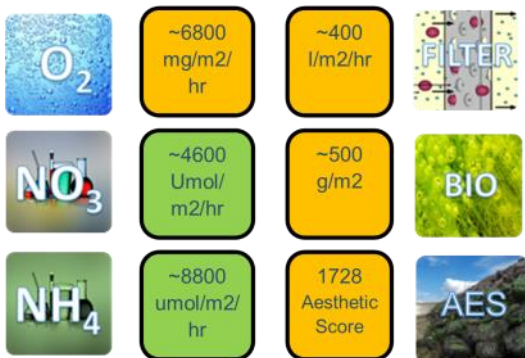


Ecosystem Functions and Services Ephemeral Dominated Shore

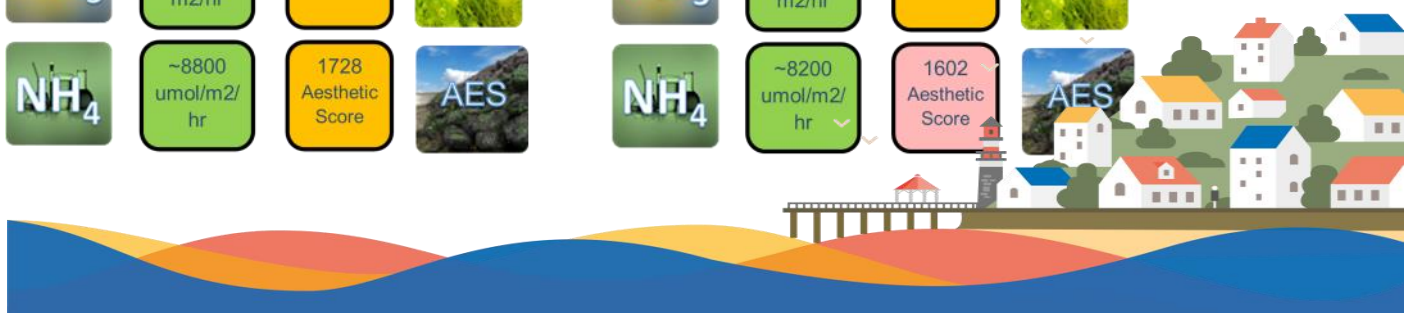
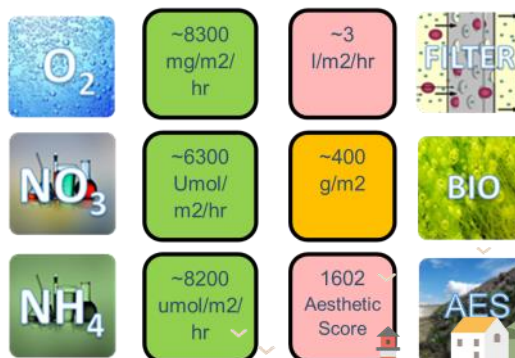


Ephemeral dominated shores show large seasonal variability in key metabolic ecosystem functions due to large bio-masses of ephemeral algae species, which often die back during the winter months. During the summer, productivity and nutrient cycling rates are high, and may be higher on artificial structures due to even larger abundances of ephemeral species. Due to the high abundances of seasonal ephemeral species, winter dieback leads to large reductions in metabolic functions and biomass across both natural and artificial shorelines. However, as communities on artificial structures (blue) typically contain slightly larger proportions of ephemeral species than their natural analogues (green), they are more likely to have slightly greater seasonal reductions in metabolic functional rates (~86-95%) and biomass (69%) during the winter as a result.

Typical Natural Shore (Summer)



Typical Artificial Shore (Summer)



Ecosystem Functions and Services

Mixed Shore

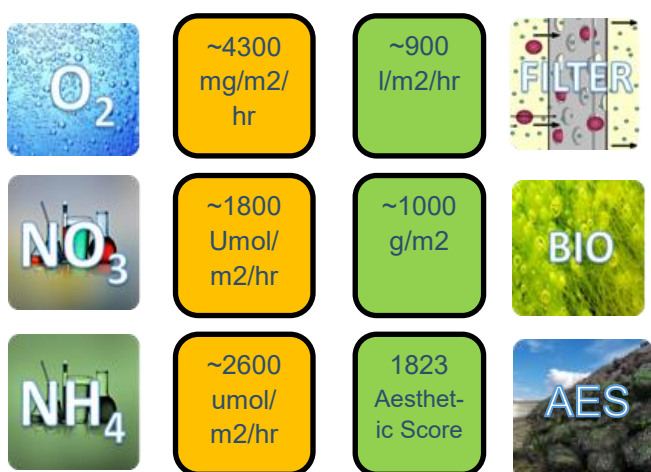


Mixed intertidal communities are often a broad mix of canopy forming fucoids, with extensive understory perennials, such as *Chondrus crispus*, *Palmaria palmata*, and *Osmundea spp.*; ephemerals such as *Ulva*, *Ceramium* and *Cladophora* species which significantly decrease in abundance over winter; and diverse animal communities including *Sabellaria alveolata*, *Nucella lapillus*, *Mytilus edulis*, and barnacle species. They are common along gently sloping natural shores, and older sloped stone coastal defence structures.

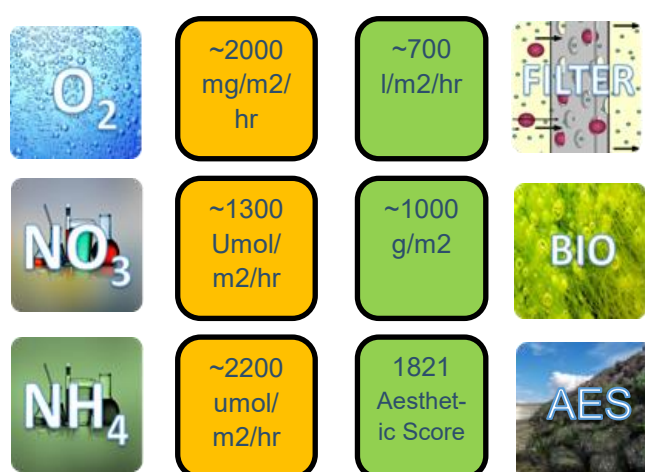
These communities can display moderate summer productivity and nutrient uptake rates due to combinations of high biomass from slow-growing larger seaweed species, and the rapid per-unit uptake rates of faster growing ephemeral green and red species. Winter diebacks of ephemerals, however do lower community metabolic rates such as nutrient uptake, but the persistence of larger canopy species somewhat reduces the impacts over more transient ephemeral dominated communities. Typically large numbers of filter feeding basal species and epibionts also can lead to moderately high clearance rates, facilitating the removal of particulates from the water and contribute to improving or maintaining water quality.

The diversity of species and functional forms in these communities and relatively high biomass can support a wide diversity of secondary organisms, and can also lead to positive human appraisals of the habitat. Aesthetic appeal is likely to be very high compared with other community types, making them particularly culturally valuable along natural coasts and supporting educational, recreational and wellbeing services.

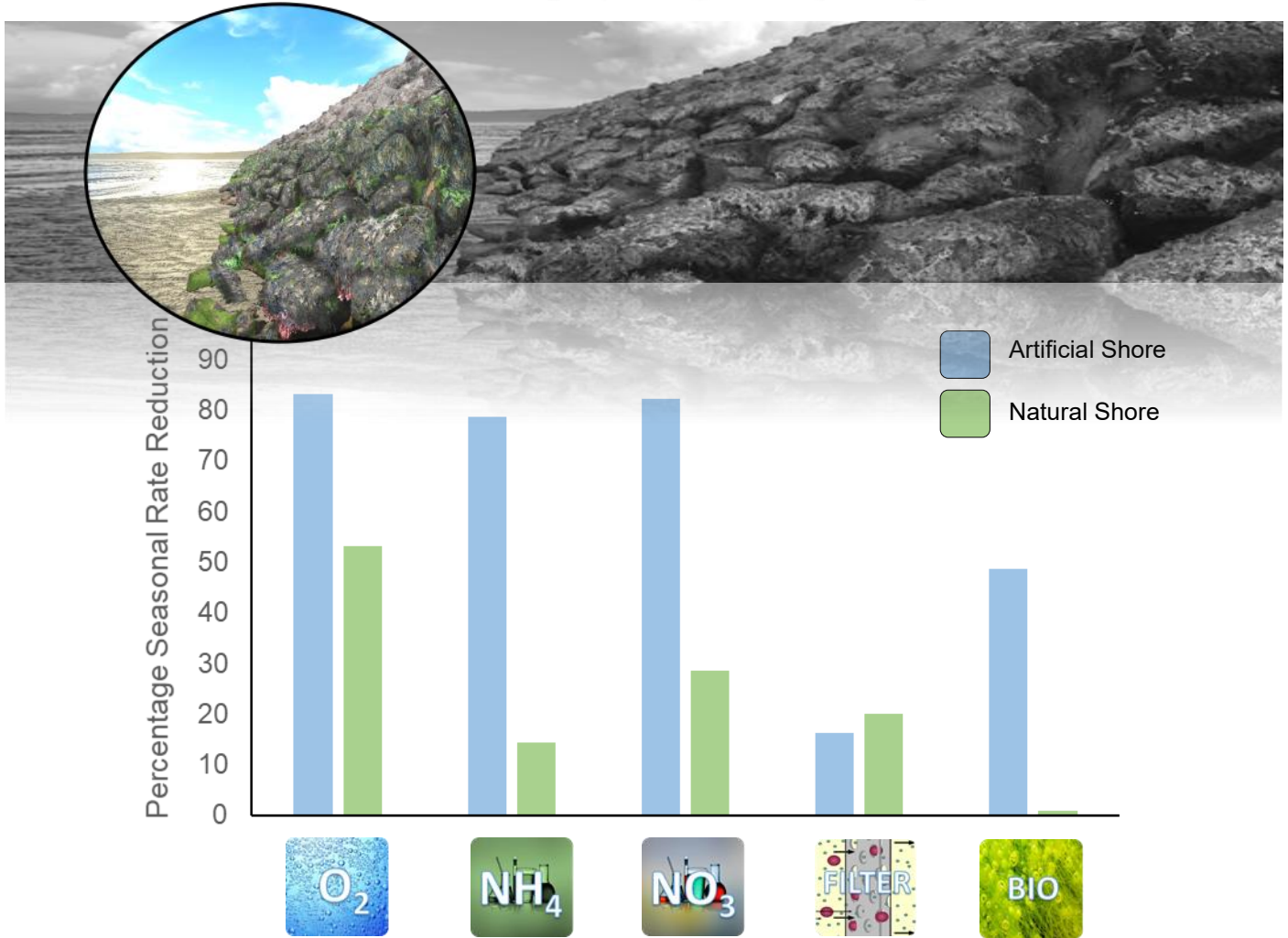
Typical Summer Community



Typical Winter Community

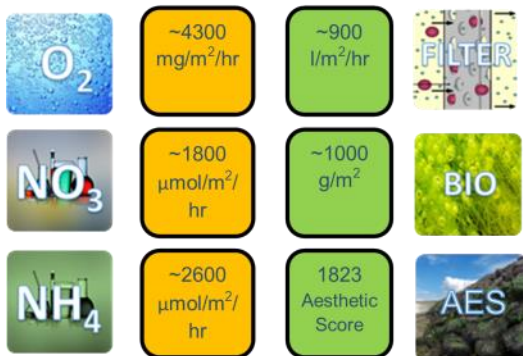


Ecosystem Functions and Services Mixed Shore

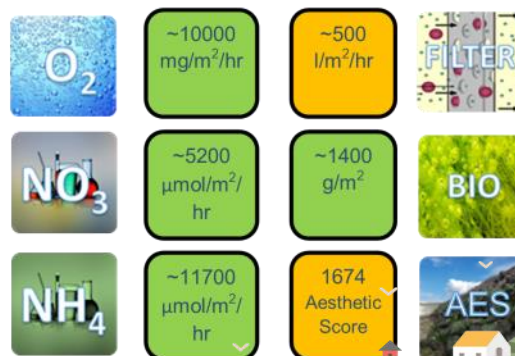


Mixed communities show large seasonal variability in some metabolic ecosystem functions, particularly for artificial shores, due to moderate biomasses of ephemeral algae species which often die back during the winter months. During the summer, productivity and nutrient cycling rates are moderate on natural shores but can be very high on artificial structures due to even larger abundances of ephemeral species. However, this abundance of ephemeral species on artificial structures (blue) compared to their natural analogues (green), mean they are more likely to have far greater seasonal reductions in metabolic functional rates (~79-84%) and biomass (55%) during the winter as a result. The abundance of large perennial species on natural shores, however, leads to much smaller reductions in function as they continue metabolic processes over the winter.

Typical Natural Shore (Summer)

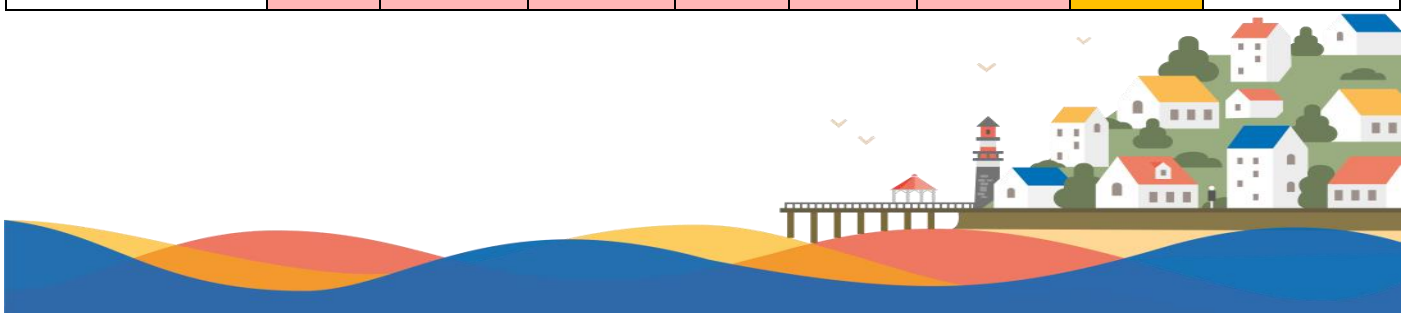


Typical Artificial Shore (Summer)



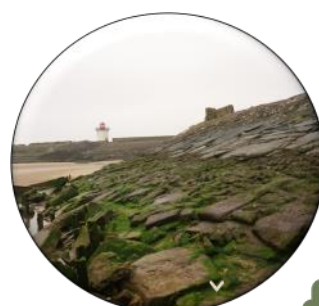
Ecosystem function summary tables - per square meter area - for net primary productivity rates (NPP), ammonium and nitrate uptake rates, water filtration (clearance) rates, total community biomass, Aesthetic score, species richness and PCA derived multifunctionality index. Common community types, with community composition from surveyed data, is represented across seasons (summer and winter) and across typical communities on artificial and natural shorelines and structures. Methodologies for calculation can be found in the "Methods" appendix at the end of the document.

	NPP (mg DO ₂ /m ² / hr)	Ammoni- um uptake (μmol/m ² / hr)	Nitrate uptake (μmol/m ² / hr)	Filtra- tion Rate (l/ m ² /hr)	Biomass (g/m ²)	ELO aesthetic score	Species Richness	Multifunctional- ity Index
Natural Shore, Summer: <i>4 μmol Nitrate and Ammonium concentration, 17c, 1000μmol PAR light</i>								
Fucoid dominated	10900	6800	2900	7	2200	1753	25	1.892
Mixed Community	4300	2600	1800	900	1000	1823	40	1.212
Barnacle dominated	2100	2100	1000	100	500	1771	23	0.699
Mussel dominated	1300	900	600	6000	900	1747	26	1.114
Ephemeral Domi- nated	6800	8800	4600	400	500	1728	17	1.451
Artificial Shore, Summer: <i>4 μmol Nitrate and Ammonium concentration, 17c, 1000μmol PAR light</i>								
Fucoid dominated	11600	12500	5700	3	1700	1626	16	2.002
Mixed Community	10000	11700	5200	500	1400	1674	25	1.915
Barnacle dominated	3200	2000	1500	15	400	1590	10	0.355
Mussel dominated	3200	2300	2500	4300	600	1642	22	0.995
Ephemeral Domi- nated	8300	8200	6300	3	400	1602	14	1.304
Natural Shore, Winter: <i>10 μmol Nitrate and 7 μmol Ammonium concentration, 10c, 300 μmol PAR light</i>								
Fucoid dominated	6200	6300	3000	5	2000	1752	25	1.612
Mixed Community	2000	2200	1300	700	1000	1821	40	1.026
Barnacle dominated	700	1500	600	100	400	1770	23	0.544
Mussel dominated	500	600	500	5200	900	1744	26	1.009
Ephemeral Domi- nated	700	2200	800	400	300	1726	17	0.494
Natural Shore, Winter: <i>10 μmol Nitrate and 7 μmol Ammonium concentration, 10c, 300 μmol PAR light</i>								
Fucoid dominated	4000	7100	2800	2	1400	1620	16	1.074
Mixed Community	1700	2500	1000	400	700	1670	25	0.559
Barnacle dominated	800	700	500	11	300	1589	10	0.073
Mussel dominated	200	300	500	3700	500	1636	22	0.505
Ephemeral Domi- nated	400	1300	700	2	100	1631	14	0.135





Ecosystem Functions and Services Appendix: Tool Guide



EFPREDICT Tool

EFPREDICT R Package

Package name: EFPREDICT

Package Version: 0.0.0.9 (Beta)

Authors: Tom Fairchild, John Griffin (Swansea University)

Managed by: Tom Fairchild <t.fairchild@swansea.ac.uk>

The EFPREDICT tool has been developed by Dr. Tom Fairchild and Dr. John Griffin of Swansea University to predict ecosystem functional rates and service indicators, as part of the Ecostructure Project. More information on the Ecostructure project can be found at <https://www.ecostructureproject.eu/>.

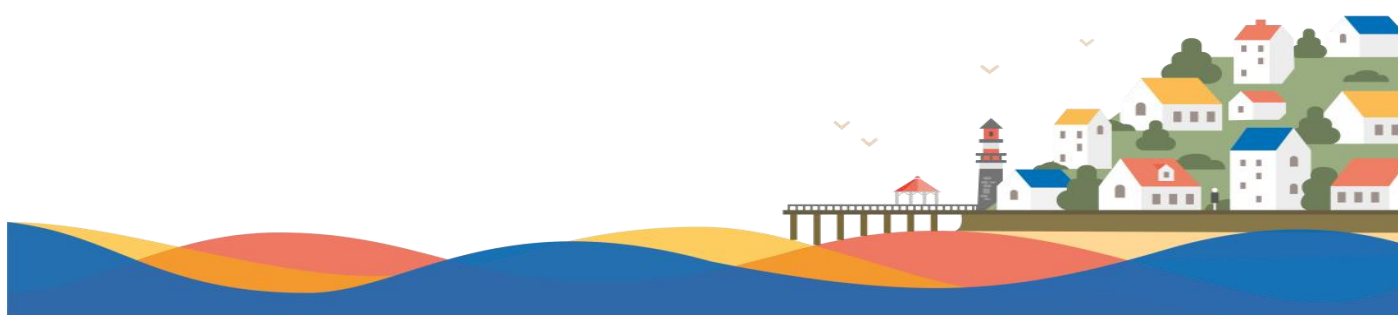
Ecostructure is part-funded by the European Regional Development Fund (ERDF) through the Ireland-Wales Cooperation Programme 2014-2020

Please note: the data provided as part of the tool is still subject to publication by members of the Ecostructure project team. If you intend to publish any data using the outputs of this tool, in part or full, you must seek permission from the authors. Additionally, if you are having difficulty accessing or using the tool, please contact t.fairchild@swansea.ac.uk.

Associated Tools

In addition to this ecosystem function predictive tool, another tool designed to predict the potential biodiversity and community composition for different artificial structures across a range of environmental contexts has been developed by Dr. Peter Lawrence as part of the Ecostructure project. You can access the tool at <https://rstudio.bangor.ac.uk/BioPredict/>.

Finally, the Conservation Evidence tool can support environmental decision makers by providing evidence for different engineering and management interventions coastal intertidal and subtidal structures which can enhance the biodiversity of these structures. Further information can be found at <https://www.conservationevidence.com/>



EFPREDICT Tool Guide

EFPREDICT R Package

Package name: EFPREDICT

Package Version: 0.0.0.9 (Beta)

Authors: Tom Fairchild, John Griffin (Swansea University)

Managed by: Tom Fairchild <t.fairchild@swansea.ac.uk>

Before starting:

This package uses excel templates to populate the required data fields from a variety of different survey formats. The excel file template “Inputs.xlsx” is provided in the distributable pack, available at <https://doi.org/10.6084/m9.figshare.c.5505186>, which has populatable input fields (instructions for the input template can be found on page X of this guide). Before beginning, please save a working copy of the template—in which you can populate the species data and environmental data - to your working directory. You may then rename this file to fit your needs. A copy of the “Outputs.xlsx” file should also be added to your working directory but this should not be modified.

This package requires other dependent packages to operate which may not automatically install, depending on your version of R or R-Studio. It is advised to install the following packages from *cran* before installing the EFPREDICT package:

```
<vegan> <readxl> <openxlsx>
```

The EFPREDICT function:

Description: The EFPREDICT function calculates a range of ecosystem processes and functions for intertidal animal and algal communities. This package is suitable to apply to artificial coastal structures and natural intertidal habitats, such as rocky reefs. It allows the predictions for oxygen fluxes (respiration, primary productivity), nutrient fluxes (uptake/excretion of ammonium and nitrate), filtration efficiency (clearance rate), carbon flux, biomass and the cultural ecosystem service indicator of aesthetic appeal.

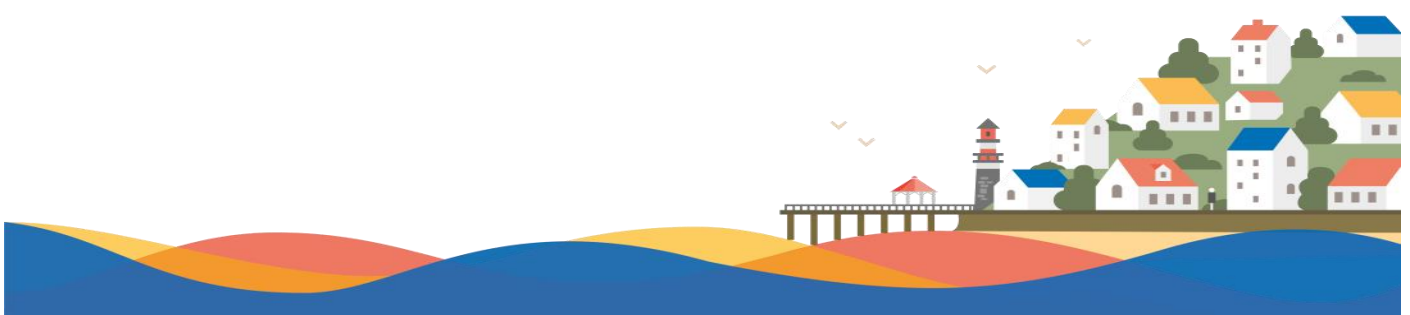
Syntax format: **EFPREDICT**(*input file, output file*)

- Input file: should be a user-modified version of the “Inputs.xlsx” template file. Use this to specify the name of the input file you wish to analyse, including the .xlsx file suffix, and bounded by quotation marks (“xxxx.xlsx”)
- Output file: user selectable file name. Please type in your preferred output file name, including the .xlsx file suffix, and bounded by quotation marks (“xxxx.xlsx”).

For example, If the input file is saved as “MumblesPierA1.xlsx” and we want to call the output file “MumPierRESULTSA1.xlsx” the function would be populated as follows:

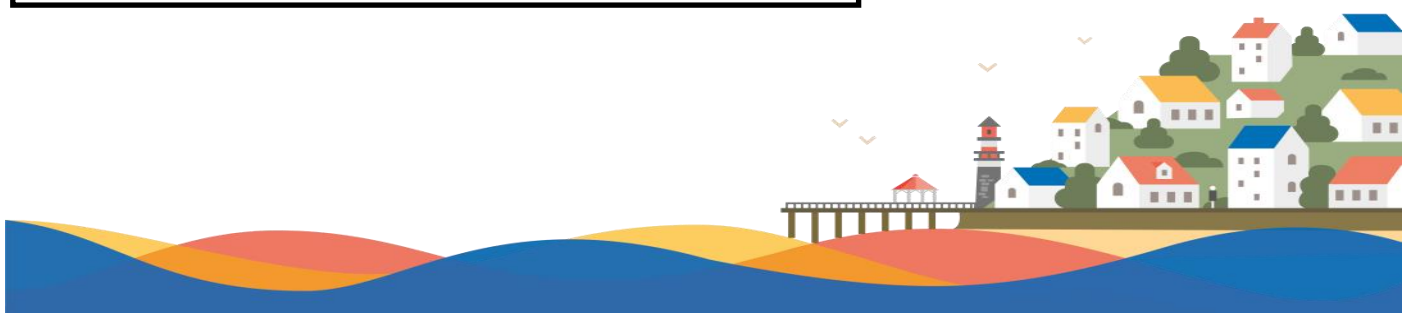
```
EFPREDICT( “MumblesPierA1.xlsx” , “MumPierRESULTSA1.xlsx”)
```

This will produce a formatted results excel file with the name “MumPierRESULTSA1.xlsx”, containing estimates and confidence intervals for each of the ecosystem functions.



EFPREDICT R Package

Finally, environmental data for the desired scenario needs to be inputted, as many functional rates strongly depend on temperature, salinity, light or nutrient concentrations. Guidance on environmental parameters is available in a guidance tab on the input sheet. You can also select the type of shore (13) for calculating aesthetic appeal, and can specify a sample number (14: just for note).



Input Data Sheet

EFPREDICT R Package

Ecosystem Function Run Output Sheet						
Ecosystem Processes	Estimate	Lower (5% CI) Estimate	Upper (95% CI) Estimate	Magnitude	Confidence	Significance
Community Oxygen Flux (mg O ₂ /m ² /hr ⁻¹)	0	0	0	No Detectable Oxygen flux (1)	Not Applicable	The community on the structure is providing no net oxygenation or oxygen uptake effects
Community Respiration Rate (mg O ₂ /m ² /hr ⁻¹)	0	0	0	No Detectable Respiration (1)	Not Applicable	No measurable oxygen production is occurring
Community Primary Productivity Rate (mg O ₂ /m ² /hr ⁻¹)	0	0	0	No Detectable Productivity (1)	Not Applicable	No measurable oxygen production is occurring
Community Ammonium Flux (μmol NH ₄ /m ² /hr ⁻¹)	0	0	0	No Detectable Ammonium Flux (1)	Not Applicable	The community on the structure is providing no net ammonium excretion or uptake
Community Ammonium Excretion Rate (μmol NH ₄ /m ² /hr ⁻¹)	0	0	0	No detectable Ammonium Excretion (1)	Not Applicable	The community on the structure is providing no ammonium excretion
Community Ammonium Uptake Rate (μmol NH ₄ /m ² /hr ⁻¹)	0	0	0	No detectable Ammonium Uptake (1)	Not Applicable	The community on the structure is providing no net ammonium excretion or uptake
Community Nitrate Uptake Rate (μmol NO ₃ /m ² /hr ⁻¹)	0	0	0	No Detectable Nitrate Uptake (1)	Not Applicable	The community on the structure is providing no net nitrate excretion or uptake
Metabolic Carbon Flux (mg C/m ² /hr ⁻¹)	0	0	0	No Detectable Oxygen flux (1)	Not Applicable	The community on the structure is providing no net carbon uptake or output effects
Community Clearance Rate (Litres cleared/hr ⁻¹)	0	0	0	No Detectable Clearance (1)	Not Applicable	The community on the structure is providing no particulate removal clearance function
Community Algal Biomass (g DW/m ²)	0	0	0	No Algal Biomass (1)	Not Applicable	The community on the structure is providing no algal biomass
Community Animal Biomass (g AFDW/m ²)	0	0	0	No Animal Biomass (1)	Not Applicable	The community on the structure is providing no animal biomass
Aesthetic Services	Estimate	Lower (5% CI) Estimate	Upper (95% CI) Estimate	Value	Confidence	Significance
Community aesthetic Preference Score (ELO)	0	0	0	Could Not Be Calculated, Insufficient Inform	Not Applicable	Insufficient information has been supplied to calculate aesthetics. Please check the input file
Community Diversity Metrics	Estimate					
Species Richness	0					
Species Evenness	0.00					
Species Diversity (Shannon)	0.00					



Ecosystem Function Run Output Sheet			
Ecosystem Processes	Estimate	Lower (5% CI) Estimate	Upper (95% CI) Estimate
Community Oxygen Flux (mg O ₂ /m ² /hr ⁻¹)	0	0	0
Community Respiration Rate (mg O ₂ /m ² /hr ⁻¹)	0	0	0
Community Primary Productivity Rate (mg O ₂ /m ² /hr ⁻¹)	0	0	0
Community Ammonium Flux (μmol NH ₄ /m ² /hr ⁻¹)	0	0	0
Community Ammonium Excretion Rate (μmol NH ₄ /m ² /hr ⁻¹)	0	0	0
Community Ammonium Uptake Rate (μmol NH ₄ /m ² /hr ⁻¹)	0	0	0
Community Nitrate Uptake Rate (μmol NO ₃ /m ² /hr ⁻¹)	0	0	0
Metabolic Carbon Flux (mg C/m ² /hr ⁻¹)	0	0	0
Community Clearance Rate (Litres cleared/hr ⁻¹)	0	0	0
Community Algal Biomass (g DW/m ²)	0		
Community Animal Biomass (g AFDW/m ²)	0		
Aesthetic Services	Estimate	Lower (5% CI) Estimate	Upper (95% CI) Estimate
Community aesthetic Preference Score (ELO)	0	0	0
Community Diversity Metrics	Estimate		
Species Richness	0		
Species Evenness	0.00		
Species Diversity (Shannon)	0.00		

In the output sheet, each major ecosystem function, process or service indicator predicted by the model is represented, accompanied by a modelled estimate for each function and upper (95% CI) and lower (5% CI) bounds for the estimate (Where applicable).

Magnitude	Confidence	Significance
No Detectable Oxygen flux (1)	Not Applicable	The community on the structure is providing no net oxygenation or oxygen uptake effects
No Detectable Respiration (1)	Not Applicable	No measurable oxygen production is occurring
No Detectable Productivity (1)	Not Applicable	No measurable oxygen production is occurring
No Detectable Ammonium Flux (1)	Not Applicable	The community on the structure is providing no net ammonium excretion or uptake
No detectable Ammonium Excretion (1)	Not Applicable	The community on the structure is providing no ammonium excretion
No detectable Ammonium Uptake (1)	Not Applicable	The community on the structure is providing no net ammonium excretion or uptake
No Detectable Nitrate Uptake (1)	Not Applicable	The community on the structure is providing no net nitrate excretion or uptake
No Detectable Oxygen flux (1)	Not Applicable	The community on the structure is providing no net carbon uptake or output effects
No detectable Clearance (1)	Not Applicable	The community on the structure is providing no particulate removal clearance function
No Algal Biomass (1)		The community on the structure is providing no algal biomass
No Animal Biomass (1)		The community on the structure is providing no animal biomass
Value	Confidence	Significance
Could Not Be Calculated, Insufficient Inform	Not Applicable	Insufficient information has been supplied to calculate aesthetics. Please check the input file

Along with the estimates of each parameter, the tool output also provides a rough summary of the results; with the magnitude and direction of the process (including easy to understand traffic-light style high-medium-low indicators), a measure of confidence in the model predictions (based on individual species performance and coverage of equivalent taxa in the training dataset), as well as a broad interpretation of the results.



Methodological Summary

EFPREDICT R Package

The EFPREDICT package has been designed to predict a range of ecosystem functions, processes and service indicators. To do this, it employs a series of predictive models which use organismal traits to cover a wide variety of species, and can interpolate function for other species which are poorly represented or which we lack functional measurements.

To understand the relationships between organism traits and functions/processes, a systematic literature review was undertaken to collate functional response data for each parameter which would be used in modelling steps. Once potential data sources were identified, each data or literature item was examined to ensure comparable methodologies were used, and to ensure that necessary environmental parameters were reported alongside functional rates. Only those which satisfied the criterion were included within the analysis dataset. From the selected literature, data was then extracted from datasets, tables or figures, along with any available trait information (if present) and environmental data, and units standardised.

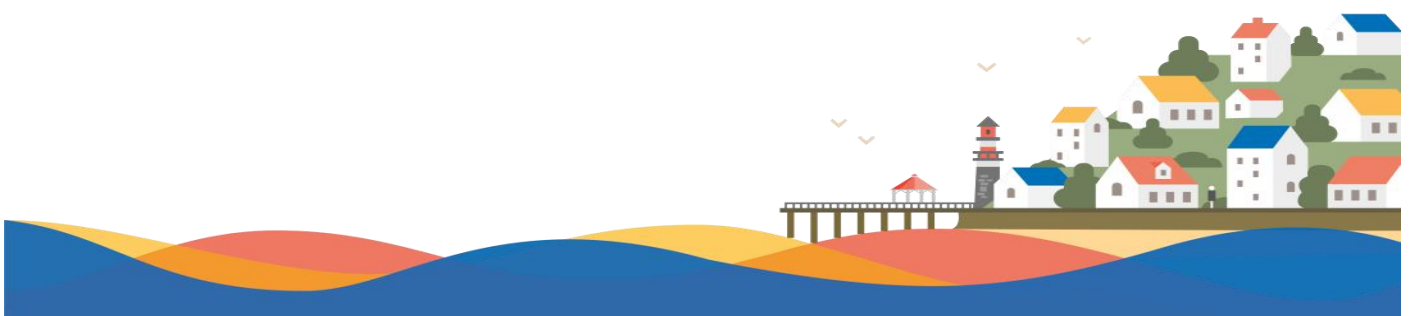
Where trait information was missing, trait averaging was employed, using data from Mauffrey et al., 2020 and data collected by the authors as part of this work. For parameters where there was poor representation across species (across functional groups or within the expected trait-space) or environmental contexts (e.g. temperature, light), we undertook additional laboratory mesocosm experiments to quantify functional rates to fill any large knowledge gaps. In total, ~6500 total datapoints were measured or extracted for the training dataset, and a further 500 were reserved for validation. Additionally to the by-species analysis of functional and process rates, a separate analysis was conducted to characterise aesthetic values for each community, based on the diversity, evenness and environmental setting, from data from Fairchild et. al. (in review) on community aesthetics.

Once the dataset was complete, linear regression (log, or log-log) or generalised additive models (GAM) were utilised to characterise the relationship between organismal traits and ecosystem functions. The traits used for each model are presented in Table 1 (page X). Models were assessed for quality of fit, and were rejected if model r^2 values were less than 0.75 or if differences between fitted and observed values were greater than $\pm 10\%$. Optimised models were then validated against a separate validation dataset to test reproducibility of results and prediction accuracy across novel species or environmental conditions. Each of the models performed well, and displayed low error rates and observed-fitted r^2 values between 0.79 and 0.94, indicating good overall model fits for novel data.

To make predictions from these validated species models, a predict function was then used to estimate each parameter for new, inputted species from community composition data, with species-level data multiplied by species biomass, and by-species rates summed to calculate functional rates at the whole community level.

LIMITATIONS OF METHODOLOGY

While the presented tool should provide a good approximation of potential functional rates under idealised conditions, the by-species models used here may not account for across and within species interactions that may alter realised functioning at the whole community level. For instance, density dependence functions were not included due to lack of available information, but could lead to shading (both of self and understory species) which might reduce productivity rates due to lower sunlight availability, or seaweed stands may reduce filter feeder efficiency by reducing water velocity and particulate loads passing over filter feeding organisms. We were also unable to capture the full range of environmental parameters that may contribute to some functions and were not included in the models as a result; for instance water flow velocity, emersion time, or water chemistry parameters. However, despite these limitations, the models should provide a good indication of functional potential and allow comparison between different habitat or community types.

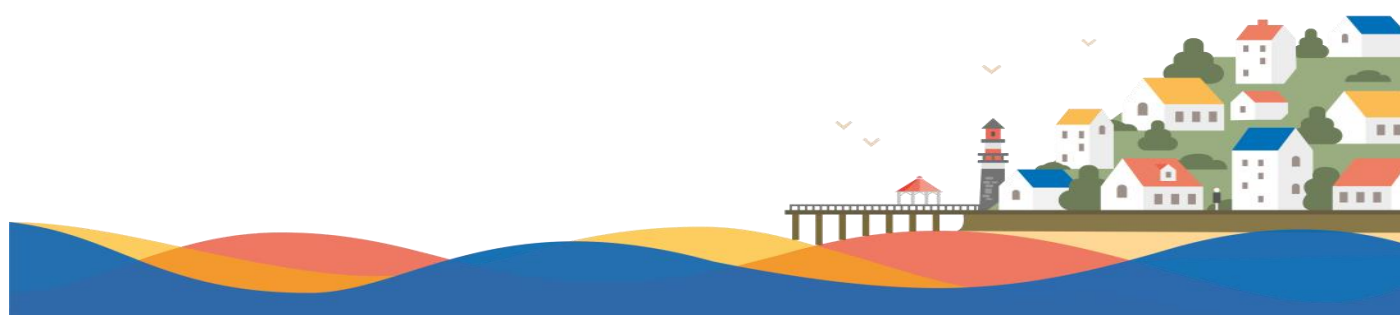


Methodological Summary

EFPREDICT R Package

Table 1: The key trait and environmental parameters driving functional rates or service indicators for each of the modelled parameters, and applicable final units returned by the models.

Parameter	Units	Key predictors
Primary Productivity	mg/m ² /hr	Trait: Colour, Thickness, Surface Area to Volume Ratio (SAV), Specific Thal- lus Area (STA), Functional Group; Environmental: Temperature, Salinity, Light Availability
Respiration (Macroalgae)	mg/m ² /hr	Trait: Colour, Surface Area to Volume Ratio (SAV), Specific Thallus Area (STA), Functional Group; Environmental: Temperature, Salinity
Respiration (Animals)	mg/m ² /hr	Trait: individual biomass (AFDW) , Functional Group, Type; Environmental: Temperature, Salinity
Nitrate Uptake	μmol/m ² /hr	Trait: Colour, Thickness, Surface Area to Volume Ratio (SAV), Specific Thal- lus Area (STA), Functional Group, Tissue Nitrogen Content; Environmen- tal: Temperature, Salinity, Nitrate Water Concentration, Light
Ammonium Uptake	μmol/m ² /hr	Trait: Colour, Thickness, Surface Area to Volume Ratio (SAV), Specific Thal- lus Area (STA), Functional Group, Tissue Nitrogen Content; Environmen- tal: Temperature, Salinity, Ammonium Water Concentration, Light
Ammonium Excretion	μmol/m ² /hr	Trait: individual biomass (AFDW) , Functional Group, Type; Environmental: Temperature, Salinity
Clearance rate	Litres/m ² /hr	Trait: individual biomass (AFDW) , Functional Group, Type; Environmental: Temperature, Salinity, Particulate Concentration
Aesthetic Score	ELO score	Community: Species Richness, Species Evenness, Functional Evenness (F.EVE), Functional Divergence (Rao's Q); Environmental: Shore Type



Data Sources

EFPREDICT R Package

Ammonium Uptake (Ahn *et al.*, 1998; Amat & Braud, 1990; Aníbal *et al.*, 2014; Bigelow, 1978; D'Elia & DeBoer, 1978; Grote, 2016; Hein *et al.*, 1995; Luo *et al.*, 2012; Martínez *et al.*, 2012; Peckol *et al.*, 1994; Rees *et al.*, 2007; Rosenberg & Ramus, 1984; Subandar *et al.*, 1993; R. B. Taylor *et al.*, 1998; Wallentinus, 1984; Fairchild *et al.* (Unpublished))

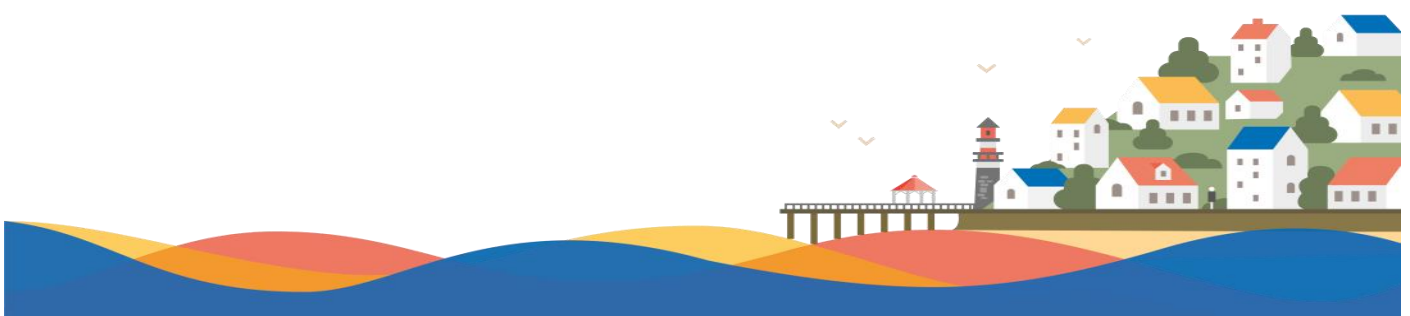
Nitrate Uptake (Ahn *et al.*, 1998; Aníbal *et al.*, 2014; Benes & Bracken, 2016; Brenchley *et al.*, 1997; Gordillo *et al.*, 2002; Luo *et al.*, 2012; Martínez *et al.*, 2012; Martínez & Rico, 2004; Naldi & Viaroli, 2002; Nguyen *et al.*, 2020; A. Pedersen *et al.*, 2004; M. F. Pedersen & Borum, 1997; Rees *et al.*, 2007; Sun *et al.*, 2015)

Primary Productivity (Mauffrey *et al.*, 2020; Blain *et al.*, 2020; Skene, 2004; Skene & Raven, 1998; Bäck & Ruuskanen, 2000; Rodgers *et al.*, 2015; Xiao *et al.*, 2016; Johansson & Snoeijs, 2002; Egilsdottir *et al.*, 2016; Haikali *et al.*, 2004; Levavasseur, 1988; Rosenberg & Ramus, 1982; Arnold & Murray, 1980; Migné *et al.*, 2015; Mathieson & Norall, 1975; Piñeiro-Corbeira *et al.*, 2018; Vidondo & Duarte, 1995; Fairchild *et al.* (Unpublished))*

Ammonium excretion (Barange Corachan *et al.*, 1989; Barrento *et al.*, 2013; Bracken *et al.*, 2018; Davy *et al.*, 2002; Durand & Regnault, 1998; Fang *et al.*, 2015; Grant & Thorpe, 1991; Haberfield *et al.*, 1975; Honda & Kikuchi, 2002; Hurd *et al.*, 1994, 2000; Jiang *et al.*, 2008; Jiménez & Ribes, 2007; Jobling, 1981; Kemp *et al.*, 2009; Markus & Lambert, 1983; Martin *et al.*, 2006; Matsakis, 1992; Migné *et al.*, 2012; Migné & Davoult, 1997; Nithart *et al.*, 1999; Regnault, 1981, 1994; Sabourin & Stickle, 1981; Sadok *et al.*, 1999; Shirley & Stickle, 1982; Sma & Baggaley, 1976; Smaal *et al.*, 1997; Spaargaren, 1982; Tagliarolo, Clavier, *et al.*, 2013; Tagliarolo *et al.*, 2012; Tagliarolo, Grall, *et al.*, 2013; E. W. Taylor & Butler, 1978; Thomsen *et al.*, 2016; Thomsen & Melzner, 2010; Vinther & Holmer, 2008; Weihrauch *et al.*, 1999; White & Walker, 1981; Widdows, 1978; Widdows *et al.*, 1984; Williamson & Rees, 1994; Wright *et al.*, 1995; Fairchild *et al.* (Unpublished))

Respiration rate (Allan *et al.*, 2006; Arnold & Murray, 1980; Bäck & Ruuskanen, 2000; Barnes & Barnes, 1969; Barrento *et al.*, 2013; Barthel, 1988; Bayne *et al.*, 1973; Blain *et al.*, 2020; Calder-Potts *et al.*, 2015; Campbell, 1975; Chaoyuan *et al.*, 1984; Clapin, 1996; Collard *et al.*, 2013; Coma, 2002; Dales, 1961; P. S. Davies, 1966; Egilsdottir *et al.*, 2016; Emson, 1977; Fisher, 1976; Fitt, 1982; Ghedini *et al.*, 2018; Gilman *et al.*, 2013; Haikali *et al.*, 2004; Hamburger *et al.*, 1983; Harland & Davies, 1995; Houlihan & Newton, 1978; Hu *et al.*, 2014; Hughes *et al.*, 1986; Johansen & Petersen, 1971; Johansson & Snoeijs, 2002; Jungblut *et al.*, 2016, 2018; Kettle & Lucas, 1987; Kübler & Raven, 1996; Laming *et al.*, 1982; Landes *et al.*, 2015; Y. S. Leung *et al.*, 2013; Mauffrey *et al.*, 2020; McMahon *et al.*, 1995; Melatunan *et al.*, 2011; Migné *et al.*, 2015; Milton, 1971; E. Navarro *et al.*, 1981; J. M. Navarro & Chaparro, 2002; Newell *et al.*, 1972; Newell & Northcroft, 1965; Nielsen *et al.*, 1995; Nishizaki & Carrington, 2014; Nithart *et al.*, 1999; Otero-Villanueva *et al.*, 2004; Petersen & Petersen, 1990; Piñeiro-Corbeira *et al.*, 2018; Regnault, 1981; Riisgård, 1991; Riisgård & Ivarsson, 1990; Rosenberg & Ramus, 1982; Sassaman & Mangum, 1970; Segelken-Voigt *et al.*, 2018; Shumway, 1978a, 1978b; Shumway *et al.*, 1988; Skene, 2004; Skene & Raven, 1998; Stickle & Sabourin, 1979; E. W. Taylor & Butler, 1978; Thomassen & Riisgård, 1995; Tytler & Davies, 1984; Van Donk & De Wilde, 1981; von Oertzen, 1983; Vopel *et al.*, 2003; Webster & Giese, 1975; YAMAMOTO, 1992; Zotin & Ozernyuk, 2016; Fairchild *et al.* (Unpublished))

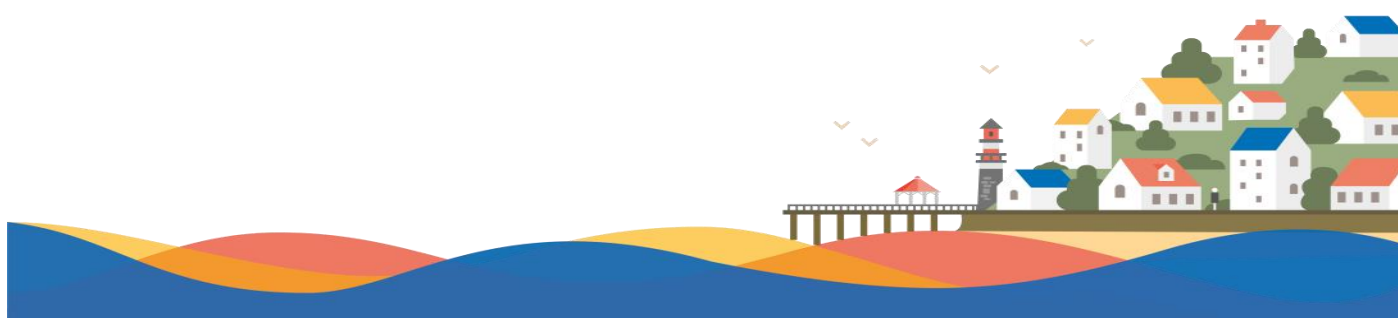
Clearance Rate (Dales, 1957; B. R. Davies *et al.*, 1989; Denis *et al.*, 2007; Diederich *et al.*, 2015; Dubois *et al.*, 2006; Hily, 1991; Laing, 2004; Lesser *et al.*, 1992; J. Y. S. Leung & Cheung, 2017; Lisbjerg & Petersen, 2000; Møhlenberg & Riisgård, 1979; Nakai *et al.*, 2018; J. M. Navarro & Chaparro, 2002; Noisette *et al.*, 2016; Petersen & Riisgård, 1992; Pleissner *et al.*, 2013; Randløv & Riisgård, 1979; Ribes *et al.*, 2003; Riisgård, 1991; Riisgård *et al.*, 1993, 2011, 2014; Riisgård & Goldson, 1997; Riisgård & Møhlenberg, 1979; Savina & Pouvreau, 2004; Shumway *et al.*, 1988; Strohmeier *et al.*, 2009; Thomassen & Riisgård, 1995; Vedel & Riisgård, 1993; Fairchild *et al.*



Data Sources: References

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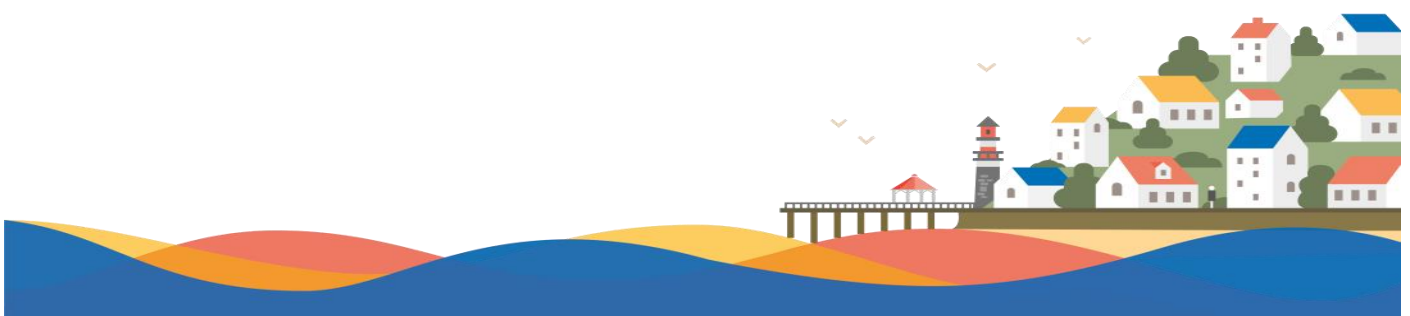
- Ahn, O., Petrell, R. J., & Harrison, P. J. (1998). Ammonium and nitrate uptake by *Laminaria saccharina* and *Nereocystis luetkeana* originating from a salmon sea cage farm. *Journal of Applied Phycology*, 10(4), 333–340. <https://doi.org/10.1023/A:1008092521651>
- Allan, E. L., Froneman, P. W., & Hodgson, A. N. (2006). Effects of temperature and salinity on the standard metabolic rate (SMR) of the caridean shrimp *Palaemon peringueyi*. *Journal of Experimental Marine Biology and Ecology*, 337(1), 103–108. <https://doi.org/10.1016/j.jembe.2006.06.006>
- Amat, M. A., & Braud, J.-P. (1990). Ammonium uptake by *Chondrus crispus* Stackhouse (Gigartinales, Rhodophyta) in culture. *Hydrobiologia*, 204(1), 467–471. <https://doi.org/10.1007/BF00040272>
- Aníbal, J., Madeira, H. T., Carvalho, L. F., Esteves, E., Veiga-Pires, C., & Rocha, C. (2014). Macroalgae mitigation potential for fish aquaculture effluents: An approach coupling nitrogen uptake and metabolic pathways using *Ulva rigida* and *Enteromorpha clathrata*. *Environmental Science and Pollution Research*, 21(23), 13324–13334. <https://doi.org/10.1007/s11356-013-2427-x>
- Arnold, K. E., & Murray, S. N. (1980). Relationships between irradiance and photosynthesis for marine benthic green algae (Chlorophyta) of differing morphologies. *Journal of Experimental Marine Biology and Ecology*, 43(2), 183–192. [https://doi.org/10.1016/0022-0981\(80\)90025-8](https://doi.org/10.1016/0022-0981(80)90025-8)
- Bäck, S., & Ruuskanen, A. (2000). Distribution and maximum growth depth of *Fucus vesiculosus* along the Gulf of Finland. *Marine Biology*, 136(2), 303–307. <https://doi.org/10.1007/s002270050688>
- Barange Corachan, M., Zabala i Limousin, M., Riera, T., & Gili, J. M. (1989). *A general approach to the in situ energy budget of Eudendrium racemosum (Cnidaria, Hydrozoa) in the Western Mediterranean*. <http://diposit.ub.edu/dspace/handle/2445/32431>
- Barnes, H., & Barnes, M. (1969). Seasonal changes in the acutely determined oxygen consumption and effect of temperature for three common cirripedes, *Balanus balanoides* (L.), *B. Balanus* (L.) and *Chthamalus stellatus* (Poli). *Journal of Experimental Marine Biology and Ecology*, 4(1), 36–50. [https://doi.org/10.1016/0022-0981\(69\)90022-7](https://doi.org/10.1016/0022-0981(69)90022-7)
- Barrento, S., Lupatsch, I., Keay, A., & Christophersen, G. (2013). Metabolic rate of blue mussels (*Mytilus edulis*) under varying post-harvest holding conditions. *Aquatic Living Resources*, 26(3).
- Barthel, D. (1988). On the ecophysiology of the sponge *Halichondria panicea* in Kiel Bight. 2. Biomass, production, energy budget and integration in environmental processes. *Marine Ecology Progress Series*. Oldendorf, 43(1), 87–93.
- Bayne, B. L., Thompson, R. J., & Widdows, J. (1973). Some Effects of Temperature and Food on the Rate of Oxygen Consumption by *Mytilus edulis* L. In W. Wieser (Ed.), *Effects of Temperature on Ectothermic Organisms: Ecological Implications and Mechanisms of Compensation* (pp. 181–193). Springer. https://doi.org/10.1007/978-3-642-65703-0_15
- Benes, K. M., & Bracken, M. E. S. (2016). Nitrate uptake varies with tide height and nutrient availability in the intertidal seaweed *Fucus vesiculosus*. *Journal of Phycology*, 52(5), 863–876. <https://doi.org/10.1111/jpy.12454>
- Bigelow, J. A. T. (1978). Nitrogen Uptake by *Fucus Spiralis* (phaeophyceae)1,2. *Journal of Phycology*, 14(3), 241–247. <https://doi.org/10.1111/j.1529-8817.1978.tb00292.x>



Data Sources: References

EFPREDICT R Package

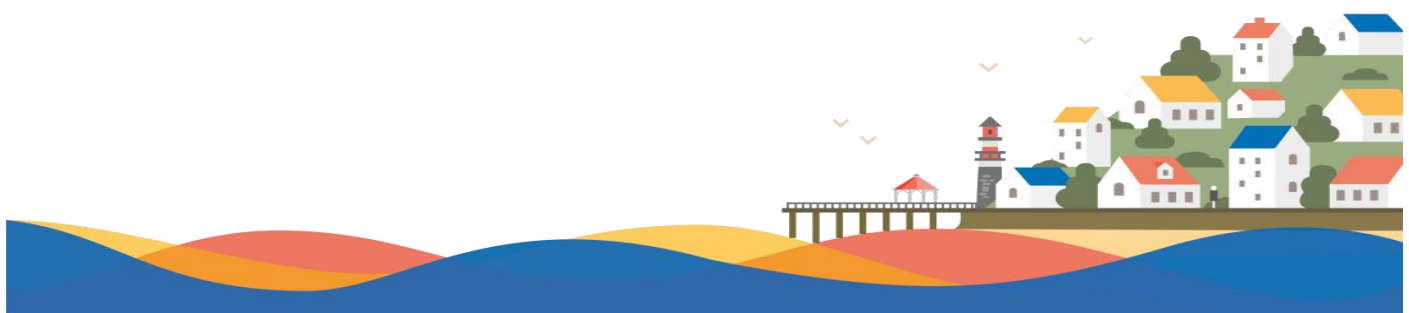
- Blain, C. O., Rees, T. A. V., Hansen, S. C., & Shears, N. T. (2020). Morphology and photosynthetic response of the kelp *Ecklonia radiata* across a turbidity gradient. *Limnology and Oceanography*, 65(3), 529–544. <https://doi.org/10.1002/lno.11321>
- Bracken, M. E. S., Oates, J. M., Badten, A. J., & Bernatchez, G. (2018). Predicting rates of consumer-mediated nutrient cycling by a diverse herbivore assemblage. *Marine Biology*, 165(10), 165. <https://doi.org/10.1007/s00227-018-3422-z>
- Brenchley, J. L., Raven, J. A., & Johnston, A. M. (1997). Resource acquisition in two intertidal fucoid seaweeds, *Fucus serratus* and *Himanthalia elongata*: Seasonal variation and effects of reproductive development. *Marine Biology*, 129(2), 367–375. <https://doi.org/10.1007/s002270050177>
- Calder-Potts, R., Spicer, J. I., Calosi, P., Findlay, H. S., & Widdicombe, S. (2015). A mesocosm study investigating the effects of hypoxia and population density on respiration and reproductive biology in the brittlestar *Ampphiura filiformis*. *Marine Ecology Progress Series*, 534, 135–147. <https://doi.org/10.3354/meps11379>
- Campbell, C. M. (1975). *Effect of temperature and other environmental variables on the metabolism of Blennius pholis L.* [Ph.D., University of Glasgow (United Kingdom)]. <https://www.proquest.com/docview/2023114408/abstract/A14DA588C948412DPQ/1>
- Chaoyuan, W., Zongcun, W., Zuosheng, P., & Jingpu, Z. (1984). A preliminary comparative study of the productivity of three economic seaweeds. *Chinese Journal of Oceanology and Limnology*, 2(1), 97–101. <https://doi.org/10.1007/BF02888397>
- Clapin, G. (1996). The Filtration Rate, Oxygen Consumption and Biomass of the Introduced Polychaete *Sabella Spallanzanii* Gmelin Within Cockburn Sound: Can it Control Phytoplankton Levels and is it an Efficient Filter Feeder? *Theses : Honours*. https://ro.ecu.edu.au/theses_hons/321
- Collard, M., Catarino, A. I., Bonnet, S., Flammang, P., & Dubois, P. (2013). Effects of CO₂-induced ocean acidification on physiological and mechanical properties of the starfish *Asterias rubens*. *Journal of Experimental Marine Biology and Ecology*, 446, 355–362. <https://doi.org/10.1016/j.jembe.2013.06.003>
- Coma, R. (2002). Seasonality of in situ respiration rate in three temperate benthic suspension feeders. *Limnology and Oceanography*, 47(1), 324–331. <https://doi.org/10.4319/lno.2002.47.1.0324>
- Dales, R. P. (1957). Some quantitative aspects of feeding in sabellid and serpulid fan worms. *Journal of the Marine Biological Association of the United Kingdom*, 36(2), 309–316. <https://doi.org/10.1017/S0025315400016817>
- Dales, R. P. (1961). Observations on the respiration of the sabellid polychaete *schizobranchia insignis*. *The Biological Bulletin*, 121(1), 82–91. <https://doi.org/10.2307/1539461>
- Davies, B. R., Stuart, V., & de Villiers, M. (1989). The filtration activity of a serpulid polychaete population (*Ficopomatus enigmaticus* (Fauvel)) and its effects on water quality in a coastal marina. *Estuarine, Coastal and Shelf Science*, 29(6), 613–620. [https://doi.org/10.1016/0272-7714\(89\)90014-0](https://doi.org/10.1016/0272-7714(89)90014-0)
- Davies, P. S. (1966). Physiological ecology of *Patella*. I. The effect of body size and temperature on metabolic rate. *Journal of the Marine Biological Association of the United Kingdom*, 46(3), 647–658. <https://doi.org/10.1017/S0025315400033397>



Data Sources: References

EFPREDICT R Package

- Davy, S. K., Trautman, D. A., Borowitzka, M. A., & Hinde, R. (2002). Ammonium excretion by a symbiotic sponge supplies the nitrogen requirements of its rhodophyte partner. *Journal of Experimental Biology*, 205(22), 3505–3511.
- D'Elia, C. F., & DeBoer, J. A. (1978). Nutritional Studies of Two Red Algae. II. Kinetics of Ammonium and Nitrate Uptake1, 2. *Journal of Phycology*, 14(3), 266–272. <https://doi.org/10.1111/j.1529-8817.1978.tb00297.x>
- Denis, L., Desroy, N., & Ropert, M. (2007). Ambient flow velocity and resulting clearance rates of the terebellid polychaete *Lanice conchilega* (Pallas, 1766). *Journal of Sea Research*, 58(3), 209–219. <https://doi.org/10.1016/j.seares.2007.03.005>
- Diederich, C. M., Chaparro, O. R., Mardones-Toledo, D. A., Garrido, G. P., Montory, J. A., & Pechenik, J. A. (2015). Differences in feeding adaptations in intertidal and subtidal suspension-feeding gastropods: Studies on *Crepidula fornicata* and *Crepidipatella peruviana*. *Marine Biology*, 162(5), 1047–1059. <https://doi.org/10.1007/s00227-015-2648-2>
- Dubois, S., Commito, J. A., Olivier, F., & Retière, C. (2006). Effects of epibionts on *Sabellaria alveolata* (L.) biogenic reefs and their associated fauna in the Bay of Mont Saint-Michel. *Estuarine, Coastal and Shelf Science*, 68(3), 635–646.
- Durand, F., & Regnault, M. (1998). Nitrogen metabolism of two portunid crabs, *carcinus maenas* and *necora puber*, during prolonged air exposure and subsequent recovery: A comparative study. *Journal of Experimental Biology*, 201(17), 2515–2528.
- Egilsdottir, H., Olafsson, J., & Martin, S. (2016). Photosynthesis and calcification in the articulated coralline alga *Ellisolandia elongata* (Corallinales, Rhodophyta) from intertidal rock pools. *European Journal of Phycology*, 51(1), 59–70. <https://doi.org/10.1080/09670262.2015.1101165>
- Emson, R. H. (1977). THE POLYCHAETE *Eulalia viridis* (O.F. Müller) AS AN ELEMENT IN THE ENERGY DYNAMICS OF INTERTIDAL MUSSEL CLUMPS. In B. F. Keegan, P. O. Ceidigh, & P. J. S. Boaden (Eds.), *Biology of Benthic Organisms* (pp. 209–214). Pergamon. <https://doi.org/10.1016/B978-0-08-021378-1.50026-9>
- Fang, J., Zhang, J., Jiang, Z., Zhao, X., Jiang, X., Du, M., Gao, Y., & Fang, J. (2015). Tolerance, oxygen consumption and ammonia excretion of *Ophiopholis sarsii vadicola* in different temperatures and salinities. *Journal of Ocean University of China*, 14(3), 549–556. <https://doi.org/10.1007/s11802-015-2513-4>
- Fisher, T. R. (1976). Oxygen uptake of the solitary tunicate *styela plicata*. *The Biological Bulletin*, 151(2), 297–305. <https://doi.org/10.2307/1540662>
- Fitt, W. K. (1982). Photosynthesis, respiration, and contribution to community productivity of the symbiotic sea anemone *Anthopleura elegantissima* (Brandt, 1835). *Journal of Experimental Marine Biology and Ecology*, 61(3), 213–232. [https://doi.org/10.1016/0022-0981\(82\)90070-3](https://doi.org/10.1016/0022-0981(82)90070-3)
- Ghedini, G., White, C. R., & Marshall, D. J. (2018). Metabolic scaling across succession: Do individual rates predict community-level energy use? *Functional Ecology*, 32(6), 1447–1456. <https://doi.org/10.1111/1365-2435.13103>
- Gilman, S. E., Wong, J. W. H., & Chen, S. (2013). Oxygen Consumption in Relation to Body Size, Wave Exposure, and Cirral Beat Behavior in the Barnacle *Balanus Glandula*. *Journal of Crustacean Biology*, 33(3), 317–322. <https://doi.org/10.1163/1937240X-00002147>



Data Sources: References

EFPREDICT R Package

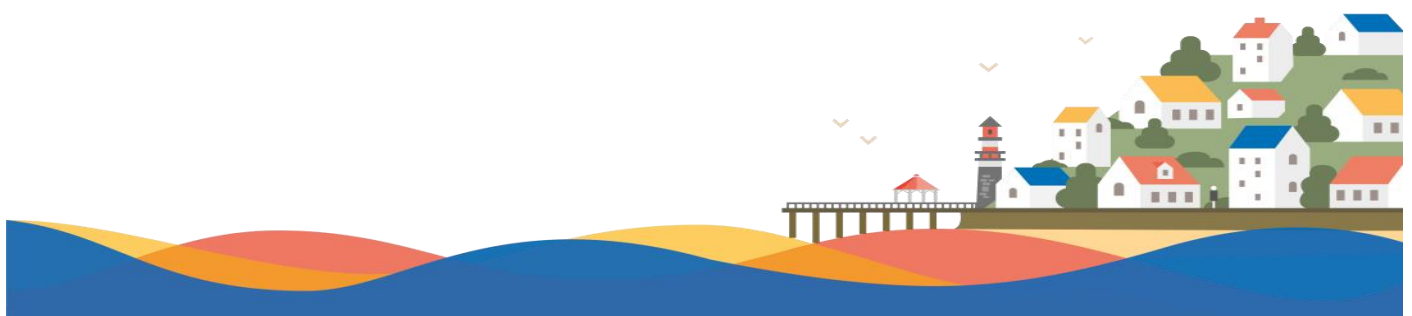
- Gordillo, F. J. L., Dring, M. J., & Savidge, G. (2002). Nitrate and phosphate uptake characteristics of three species of brown algae cultured at low salinity. *Marine Ecology Progress Series*, 234, 111–118. <https://doi.org/10.3354/meps234111>
- Grant, J., & Thorpe, B. (1991). Effects of Suspended Sediment on Growth, Respiration, and Excretion of the Soft-Shell Clam (*Mya arenaria*). *Canadian Journal of Fisheries and Aquatic Sciences*, 48(7), 1285–1292. <https://doi.org/10.1139/f91-154>
- Grote, B. (2016). Bioremediation of aquaculture wastewater: Evaluating the prospects of the red alga *Palmaria palmata* (Rhodophyta) for nitrogen uptake. *Journal of Applied Phycology*, 28(5), 3075–3082. <https://doi.org/10.1007/s10811-016-0848-x>
- Haberfield, E. C., Haas, L. W., & Hammen, C. S. (1975). Early ammonia release by a polychaete *Nereis virens* and a crab *Carcinus maenas* in diluted sea water. *Comparative Biochemistry and Physiology Part A: Physiology*, 52(3), 501–503. [https://doi.org/10.1016/S0300-9629\(75\)80072-7](https://doi.org/10.1016/S0300-9629(75)80072-7)
- Haïkali, B. E., Bensoussan, N., Romano, J. C., & Bousquet, V. (2004). Estimation of photosynthesis and calcification rates of *Corallina elongata* Ellis and Solander, 1786, by measurements of dissolved oxygen, pH and total alkalinity. *Scientia Marina*, 68(1), 45–56. <https://doi.org/10.3989/scimar.2004.68n145>
- Hamburger, K., Møhlenberg, F., Randløv, A., & Riisgård, H. U. (1983). Size, oxygen consumption and growth in the mussel *Mytilus edulis*. *Marine Biology*, 75(2), 303–306. <https://doi.org/10.1007/BF00406016>
- Harland, A. D., & Davies, P. S. (1995). Symbiont photosynthesis increases both respiration and photosynthesis in the symbiotic sea anemone *Anemonia viridis*. *Marine Biology*, 123(4), 715–722. <https://doi.org/10.1007/BF00349114>
- Hein, Pedersen, F. M., & Sand-Jensen. (1995). Size-dependent nitrogen uptake in micro- and macroalgae. *Marine Ecology Progress Series*, 118, 247–253. <https://doi.org/10.3354/meps118247>
- Hily, C. (1991). Is the activity of benthic suspension feeders a factor controlling water quality in the Bay of Brest?. *Marine Ecology Progress Series*. Oldendorf, 69(1), 179–188.
- Honda, H., & Kikuchi, K. (2002). Nitrogen budget of polychaete *Perinereis nuntia vallata* fed on the feces of Japanese flounder. *Fisheries Science*, 68(6), 1304–1308. <https://doi.org/10.1046/j.1444-2906.2002.00568.x>
- Houlihan, D. F., & Newton, J. R. L. (1978). RESPIRATION OF PATELLA VULGATA ON THE SHORE. In D. S. McLUSKY & A. J. Berry (Eds.), *Physiology and Behaviour of Marine Organisms* (pp. 39–46). Pergamon. <https://doi.org/10.1016/B978-0-08-021548-8.50011-5>
- Hu, M. Y., Casties, I., Stumpp, M., Ortega-Martinez, O., & Dupont, S. (2014). Energy metabolism and regeneration are impaired by seawater acidification in the infaunal brittlestar *Amphiura filiformis*. *Journal of Experimental Biology*, 217(13), 2411–2421. <https://doi.org/10.1242/jeb.100024>
- Hughes, D. J., Hughes, R. N., Harper, J. L., Rosen, B. R., & White, J. (1986). Metabolic implications of modularity: Studies on the respiration and growth of *Electra pilosa*. *Philosophical Transactions of the Royal Society of London. B, Biological Sciences*, 313(1159), 23–29. <https://doi.org/10.1098/rstb.1986.0023>



Data Sources: References

EFPREDICT R Package

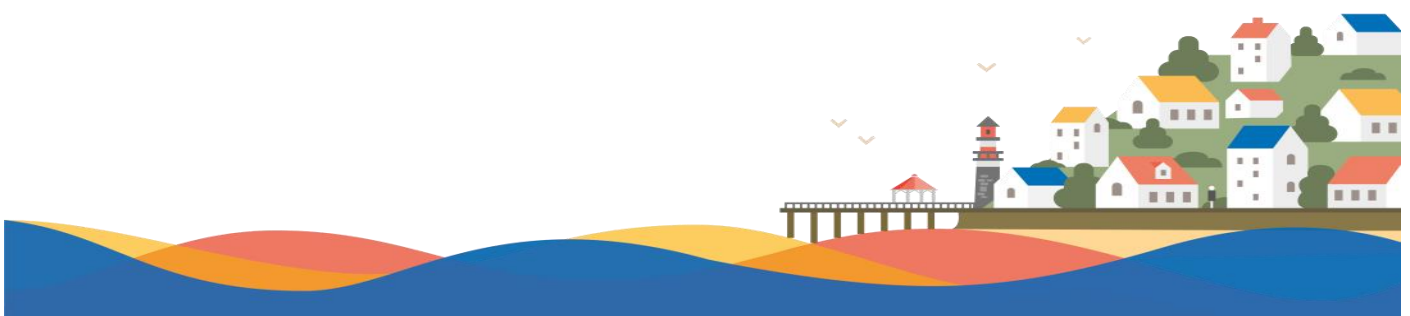
- Hurd, C. L., Durante, K. M., Chia, F.-S., & Harrison, P. J. (1994). Effect of bryozoan colonization on inorganic nitrogen acquisition by the kelps *Agarum fimbriatum* and *Macrocystis integrifolia*. *Marine Biology*, 121(1), 167–173. <https://doi.org/10.1007/BF00349486>
- Hurd, C. L., Durante, K. M., & Harrison, P. J. (2000). Influence of bryozoan colonization on the physiology of the kelp *Macrocystis integrifolia* (Laminariales, Phaeophyta) from nitrogen-rich and -poor sites in Barkley Sound, British Columbia, Canada. *Phycologia*, 39(5), 435–440. <https://doi.org/10.2216/i0031-8884-39-5-435.1>
- Jiang, A., Lin, J., & Wang, C. (2008). Physiological energetics of the ascidian *Styela clava* in relation to body size and temperature. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology*, 149(2), 129–136. <https://doi.org/10.1016/j.cbpa.2006.08.047>
- Jiménez, E., & Ribes, M. (2007). Sponges as a source of dissolved inorganic nitrogen: Nitrification mediated by temperate sponges. *Limnology and Oceanography*, 52(3), 948–958. <https://doi.org/10.4319/lo.2007.52.3.0948>
- Jobling, M. (1981). Some effects of temperature, feeding and body weight on nitrogenous excretion in young plaice *Pleuronectes platessa* L. *Journal of Fish Biology*, 18(1), 87–96. <https://doi.org/10.1111/j.1095-8649.1981.tb03763.x>
- Johansen, K., & Petersen, J. A. (1971). Gas exchange and active ventilation in a starfish, *Pteraster tessellatus*. *Zeitschrift Für Vergleichende Physiologie*, 71(4), 365–381. <https://doi.org/10.1007/BF00302373>
- Johansson, G., & Snoeijs, P. (2002). Macroalgal photosynthetic responses to light in relation to thallus morphology and depth zonation. *Marine Ecology Progress Series*, 244, 63–72. <https://doi.org/10.3354/meps244063>
- Jungblut, S., Boos, K., McCarthy, M. L., Saborowski, R., & Hagen, W. (2018). Invasive versus native brachyuran crabs in a European rocky intertidal: Respiratory performance and energy expenditures. *Marine Biology*, 165(3), 54. <https://doi.org/10.1007/s00227-018-3313-3>
- Jungblut, S., Boos, K., Saborowski, R., & Hagen, W. (2016, September 28). Energetic demand of the invasive crab *Hemigrapsus sanguineus* and the native *Carcinus maenas* at Helgoland, North Sea. *EPIC351st European Marine Biology Symposium, Rhodes, Greece, 2016-09-26-2016-09-30 Rhodes, Greece, Hellenic Centre for Marine Research*. 51st European Marine Biology Symposium, Rhodes, Greece. <https://epic.awi.de/id/eprint/42265/>
- Kemp, J. O. G., Britz, P. J., & Cockcroft, A. C. (2009). Ammonia excretion dynamics in the east coast rock lobster *Panulirus homarus rubellus*. *Aquaculture*, 286(3–4), 296–300.
- Kettle, B. T., & Lucas, J. S. (1987). Biometric Relationships Between Organ Indices, Fecundity, Oxygen Consumption and Body Size in *Acanthaster Planci* (L.) (Echinodermata; Asteroidea). *Bulletin of Marine Science*, 41(2), 541–551.
- Kübler, J. E., & Raven, J. A. (1996). Nonequilibrium Rates of Photosynthesis and Respiration Under Dynamic Light Supply1. *Journal of Phycology*, 32(6), 963–969. <https://doi.org/10.1111/j.0022-3646.1996.00963.x>
- Laing, I. (2004). Filtration of king scallops (*Pecten maximus*). *Aquaculture*, 240(1), 369–384. <https://doi.org/10.1016/j.aquaculture.2004.02.002>
- Laming, P. R., Funston, C. W., Roberts, D., & Armstrong, M. J. (1982). Behavioural, physiological and morphological adaptations of the shanny (*Blennius pholis*) to the intertidal habitat. *Journal of the Marine Biological Association of the United Kingdom*, 62(2), 329–338. <https://doi.org/10.1017/S0025315400057313>



Data Sources: References

EFPREDICT R Package

- Landes, A., Dolmer, P., Poulsen, L. K., Petersen, J. K., & Vismann, B. (2015). Growth and Respiration in Blue Mussels (*Mytilus* spp.) from Different Salinity Regimes. *Journal of Shellfish Research*, 34(2), 373–382. <https://doi.org/10.2983/035.034.0220>
- Lesser, M. P., Shumway, S. E., Cucci, T., & Smith, J. (1992). Impact of fouling organisms on mussel rope culture: Interspecific competition for food among suspension-feeding invertebrates. *Journal of Experimental Marine Biology and Ecology*, 165(1), 91–102. [https://doi.org/10.1016/0022-0981\(92\)90291-H](https://doi.org/10.1016/0022-0981(92)90291-H)
- Leung, J. Y. S., & Cheung, N. K. M. (2017). Feeding behaviour of a serpulid polychaete: Turning a nuisance species into a natural resource to counter algal blooms? *Marine Pollution Bulletin*, 115(1), 376–382. <https://doi.org/10.1016/j.marpolbul.2016.12.035>
- Leung, Y. S., Shin, P. K. S., Qiu, J. W., Ang, P. O., Chiu, J. M. Y., Thiyagarajan, V., & Cheung, S. G. (2013). Physiological and behavioural responses of different life stages of a serpulid polychaete to hypoxia. *Marine Ecology Progress Series*, 477, 135–145. <https://doi.org/10.3354/meps10175>
- Levavasseur, G. (1988). *Stratégie de production de Sargassum muticum (Yendo) Fensholt. Etude écophysiological de la composition pigmentaire et de la capacité photosynthétique*. <https://archimer.ifremer.fr/doc/00077/18827/>
- Lisbjerg, D., & Petersen, J. K. (2000). Clearance capacity of *Electra bellula* (Bryozoa) in seagrass meadows of Western Australia. *Journal of Experimental Marine Biology and Ecology*, 244(2), 285–296. [https://doi.org/10.1016/S0022-0981\(99\)00147-1](https://doi.org/10.1016/S0022-0981(99)00147-1)
- Luo, M. B., Liu, F., & Xu, Z. L. (2012). Growth and nutrient uptake capacity of two co-occurring species, *Ulva prolifera* and *Ulva linza*. *Aquatic Botany*, 100, 18–24. <https://doi.org/10.1016/j.aquabot.2012.03.006>
- Markus, J. A., & Lambert, C. C. (1983). Urea and ammonia excretion by solitary ascidians. *Journal of Experimental Marine Biology and Ecology*, 66(1), 1–10. [https://doi.org/10.1016/0022-0981\(83\)90023-0](https://doi.org/10.1016/0022-0981(83)90023-0)
- Martin, S., Thouzeau, G., Chauvaud, L., Jean, F., Guérin, L., & Clavier, J. (2006). Respiration, calcification, and excretion of the invasive slipper limpet, *Crepidula fornicata* L.: Implications for carbon, carbonate, and nitrogen fluxes in affected areas. *Limnology and Oceanography*, 51(5), 1996–2007. <https://doi.org/10.4319/lo.2006.51.5.1996>
- Martínez, B., Pato, L. S., & Rico, J. M. (2012). Nutrient uptake and growth responses of three intertidal macroalgae with perennial, opportunistic and summer-annual strategies. *Aquatic Botany*, 96(1), 14–22. <https://doi.org/10.1016/j.aquabot.2011.09.004>
- Martínez, B., & Rico, J. M. (2004). Inorganic Nitrogen and Phosphorus Uptake Kinetics in *Palmaria Palmata* (rhodophyta)1. *Journal of Phycology*, 40(4), 642–650. <https://doi.org/10.1111/j.1529-8817.2004.03116.x>
- Mathieson, A. C., & Norall, T. L. (1975). Photosynthetic studies of *Chondrus crispus*. *Marine Biology*, 33(3), 207–213. <https://doi.org/10.1007/BF00390924>
- Matsakis, S. (1992). Ammonia excretion rate of *Clytia* spp. hydromedusae (Cnidaria, Thecata): Effects of individual dry weight, temperature and food availability. *Marine Ecology Progress Series*, 87, 55–63. <https://doi.org/10.3354/meps087055>



Data Sources: References

EFPREDICT R Package

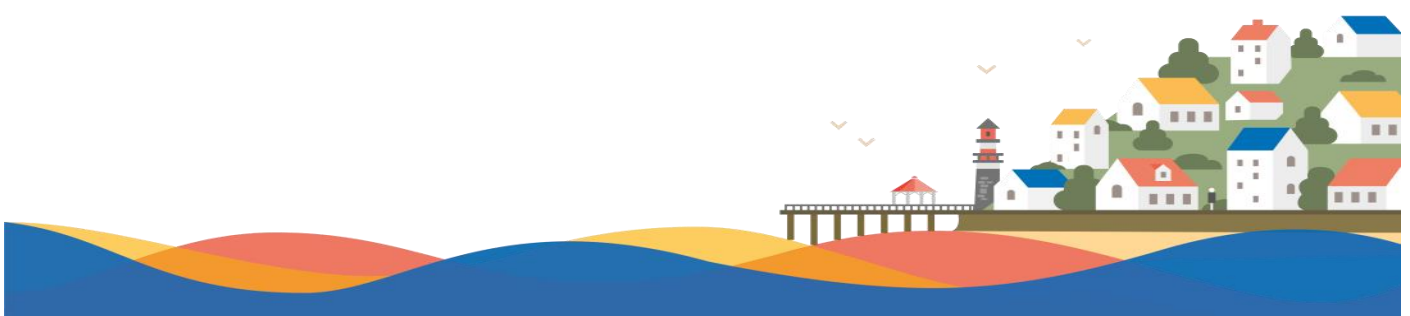
- Mauffrey, A. R. L., Cappelatti, L., & Griffin, J. N. (2020). Seaweed functional diversity revisited: Confronting traditional groups with quantitative traits. *Journal of Ecology*, 108(6), 2390–2405. <https://doi.org/10.1111/1365-2745.13460>
- McMahon, R. F., Russell-Hunter, W. D., & Aldridge, D. W. (1995). Lack of metabolic temperature compensation in the intertidal gastropods, *Littorina saxatilis* (Olivi) and *L. obtusata* (L.). In P. J. Mill & C. D. McQuaid (Eds.), *Advances in Littorinid Biology* (pp. 89–100). Springer Netherlands. https://doi.org/10.1007/978-94-011-0435-7_9
- Melatunan, S., Calosi, P., Rundle, S. D., Moody, A. J., & Widdicombe, S. (2011). Exposure to Elevated Temperature and Pco₂ Reduces Respiration Rate and Energy Status in the Periwinkle *Littorina littorea*. *Physiological and Biochemical Zoology*, 84(6), 583–594. <https://doi.org/10.1086/662680>
- Migné, A., & Davoult, D. (1997). Ammonium excretion in two benthic cnidarians: *Alcyonium digitatum* (Linnaeus, 1758) and *Urticina felina* (Linnaeus, 1767). *Journal of Sea Research*, 37(1), 101–107. [https://doi.org/10.1016/S1385-1101\(97\)00002-6](https://doi.org/10.1016/S1385-1101(97)00002-6)
- Migné, A., Delebecq, G., Davoult, D., Spilmont, N., Menu, D., & Gévaert, F. (2015). Photosynthetic activity and productivity of intertidal macroalgae: In situ measurements, from thallus to community scale. *Aquatic Botany*, 123, 6–12. <https://doi.org/10.1016/j.aquabot.2015.01.005>
- Migné, A., Riera, P., Janquin, M. A., Leroux, C., Muths, D., & Davoult, D. (2012). Carbon and nitrogen assimilation by the suspensionfeeding brittle-star *Ophiothrix fragilis* from two localities in the English Channel. *Vie et Milieu / Life & Environment*, 62(2), 47–53.
- Milton, P. (1971). Oxygen consumption and osmoregulation in the shanny, *Blennius pholis*. *Journal of the Marine Biological Association of the United Kingdom*, 51(2), 247–265. <https://doi.org/10.1017/S0025315400031763>
- Møhlenberg, F., & Riisgård, H. U. (1979). Filtration rate, using a new indirect technique, in thirteen species of suspension-feeding bivalves. *Marine Biology*, 54(2), 143–147. <https://doi.org/10.1007/BF00386593>
- Nakai, S., Shibata, J., Umehara, A., Okuda, T., & Nishijima, W. (2018). Filtration Rate of the Ascidian *Ciona savignyi* and Its Possible Impact. *Thalassas: An International Journal of Marine Sciences*, 34(2), 271–277. <https://doi.org/10.1007/s41208-017-0061-y>
- Naldi, M., & Viaroli, P. (2002). Nitrate uptake and storage in the seaweed *Ulva rigida* C. Agardh in relation to nitrate availability and thallus nitrate content in a eutrophic coastal lagoon (Sacca di Goro, Po River Delta, Italy). *Journal of Experimental Marine Biology and Ecology*, 269(1), 65–83. [https://doi.org/10.1016/S0022-0981\(01\)00387-2](https://doi.org/10.1016/S0022-0981(01)00387-2)
- Navarro, E., Ortega, M. M., & Madariaga, José M. (1981). Effect of body size, temperature and shore level on aquatic and aerial respiration of *Actinia equina* (L.) (Anthozoa). *Journal of Experimental Marine Biology and Ecology*, 53(2), 153–162. [https://doi.org/10.1016/0022-0981\(81\)90016-2](https://doi.org/10.1016/0022-0981(81)90016-2)
- Navarro, J. M., & Chaparro, O. R. (2002). Grazing–filtration as feeding mechanisms in motile specimens of *Crepidula fecunda* (Gastropoda: Calyptraeidae). *Journal of Experimental Marine Biology and Ecology*, 270(1), 111–122. [https://doi.org/10.1016/S0022-0981\(02\)00013-8](https://doi.org/10.1016/S0022-0981(02)00013-8)
- Newell, R. C., Ahsanullah, M., & Pye, V. I. (1972). Aerial and aquatic respiration in the shore crab *Carcinus maenas* (L.). *Comparative Biochemistry and Physiology Part A: Physiology*, 43(2), 239–252. [https://doi.org/10.1016/0300-9629\(72\)90182-X](https://doi.org/10.1016/0300-9629(72)90182-X)



Data Sources: References

EFPREDICT R Package

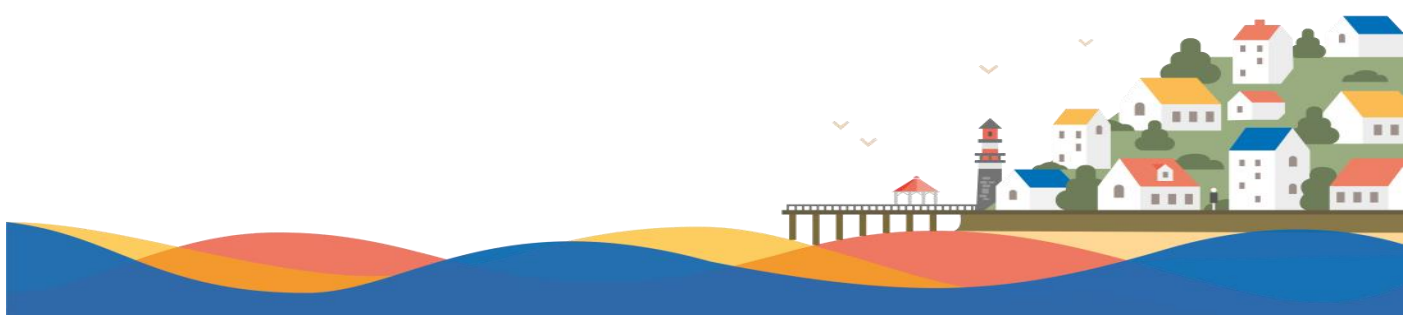
- Newell, R. C., & Northcroft, H. R. (1965). The relationship between cirral activity and oxygen uptake in *Balanus balanoides*. *Journal of the Marine Biological Association of the United Kingdom*, 45(2), 387–403. <https://doi.org/10.1017/S0025315400054916>
- Nguyen, H. T., Pritchard, D. W., & Hepburn, C. D. (2020). Nitrogen and phosphorus ecophysiology of coralline algae. *Journal of Applied Phycology*, 1–15.
- Nielsen, A., Eriksen, E., Iversen, J., & Riisgård, H. (1995). Feeding, growth and respiration in the polychaetes *Nereis diversicolor* (facultative filter-feeder) and *N. virens* (omnivorous)-a comparative study. *Marine Ecology Progress Series*, 125, 149–158. <https://doi.org/10.3354/meps125149>
- Nishizaki, M. T., & Carrington, E. (2014). The effect of water temperature and flow on respiration in barnacles: Patterns of mass transfer versus kinetic limitation. *Journal of Experimental Biology*, 217(12), 2101–2109. <https://doi.org/10.1242/jeb.101030>
- Nithart, M., Alliot, E., & Salen-Picard, C. (1999). Production, respiration and ammonia excretion of two polychaete species in a north Norfolk saltmarsh. *Journal of the Marine Biological Association of the United Kingdom*, 79(6), 1029–1037. <https://doi.org/10.1017/S0025315499001265>
- Noisette, F., Bordeyne, F., Davoult, D., & Martin, S. (2016). Assessing the physiological responses of the gastropod *Crepidula fornicata* to predicted ocean acidification and warming. *Limnology and Oceanography*, 61(2), 430–444. <https://doi.org/10.1002/lno.10225>
- Otero-Villanueva, M. del M., Kelly, M. S., & Burnell, G. (2004). How diet influences energy partitioning in the regular echinoid *Psammechinus miliaris*; constructing an energy budget. *Journal of Experimental Marine Biology and Ecology*, 304(2), 159–181. <https://doi.org/10.1016/j.jembe.2003.12.002>
- Peckol, P., DeMeo-Anderson, B., Rivers, J., Valiela, I., Maldonado, M., & Yates, J. (1994). Growth, nutrient uptake capacities and tissue constituents of the macroalgae *Cladophora vagabunda* and *Gracilaria tikvahiae* related to site-specific nitrogen loading rates. *Marine Biology*, 121(1), 175–185. <https://doi.org/10.1007/BF00349487>
- Pedersen, A., Kraemer, G., & Yarish, C. (2004). The effects of temperature and nutrient concentrations on nitrate and phosphate uptake in different species of *Porphyra* from Long Island Sound (USA). *Journal of Experimental Marine Biology and Ecology*, 312(2), 235–252. <https://doi.org/10.1016/j.jembe.2004.05.021>
- Pedersen, M. F., & Borum, J. (1997). Nutrient control of estuarine macroalgae: Growth strategy and the balance between nitrogen requirements and uptake. *Marine Ecology Progress Series*, 161, 155–163. <https://doi.org/10.3354/meps161155>
- Petersen, J. K., & Petersen, G. I. (1990). Tolerance, behaviour and oxygen consumption in the sand goby, *Pomatoschistus minutus* (Pallas), exposed to hypoxia. *Journal of Fish Biology*, 37(6), 921–933. <https://doi.org/10.1111/j.1095-8649.1990.tb03596.x>
- Petersen, J. K., & Riisgård, H. U. (1992). Filtration capacity of the ascidian *Ciona intestinalis* and its grazing impact in a shallow fjord. *Marine Ecology Progress Series*, 88(1), 9–17.
- Piñeiro-Corbeira, C., Barreiro, R., Cremades, J., & Arenas, F. (2018). Seaweed assemblages under a climate change scenario: Functional responses to temperature of eight intertidal seaweeds match recent abundance shifts. *Scientific Reports*, 8(1), 12978. <https://doi.org/10.1038/s41598-018-31357-x>



Data Sources: References

EFPREDICT R Package

- Pleissner, D., Lundgreen, K., Lüsow, F., & Riisgård, H. U. (2013). Fluorometer Controlled Apparatus Designed for Long-Duration Algal-Feeding Experiments and Environmental Effect Studies with Mussels. *Journal of Marine Biology*, 2013, e401961. <https://doi.org/10.1155/2013/401961>
- Randløv, A., & Riisgård, H. U. (1979). Efficiency of Particle Retention and Filtration Rate in Four Species of Ascidians. *Marine Ecology Progress Series*, 1(1), 55–59.
- Rees, T. a. V., Dobson, B. C., Bijl, M., & Morelissen, B. (2007). Kinetics of nitrate uptake by New Zealand marine macroalgae and evidence for two nitrate transporters in *Ulva intestinalis* L. *Hydrobiologia*, 586(1), 135–141. <https://doi.org/10.1007/s10750-006-0569-2>
- Regnault, M. (1981). Respiration and ammonia excretion of the shrimp *Crangon crangon* L.: Metabolic response to prolonged starvation. *Journal of Comparative Physiology*, 141(4), 549–555. <https://doi.org/10.1007/BF01101478>
- Regnault, M. (1994). Effect of air exposure on ammonia excretion and ammonia content of branchial water of the crab *Cancer pagurus*. *Journal of Experimental Zoology*, 268(3), 208–217. <https://doi.org/10.1002/jez.1402680305>
- Ribes, M., Coma, R., & Rossi, S. (2003). Natural feeding of the temperate asymbiotic octocoral-gorgonian *Leptogorgia sarmentosa* (Cnidaria: Octocorallia). *Marine Ecology Progress Series*, 254, 141–150. <https://doi.org/10.3354/meps254141>
- Riisgård, H. U. (1991). Suspension feeding in the polychaete *Nereis diversicolor*. *Mar. Ecol. Prog. Ser.*, 70(1), 19–37.
- Riisgård, H. U., Egede, P. P., & Barreiro Saavedra, I. (2011). Feeding Behaviour of the Mussel, *Mytilus edulis*: New Observations, with a Minireview of Current Knowledge. *Journal of Marine Biology*, 2011, e312459. <https://doi.org/10.1155/2011/312459>
- Riisgård, H. U., & Goldson, A. (1997). Minimal scaling of the lophophore filter-pump in ectoprocts (Bryozoa) excludes physiological regulation of filtration rate to nutritional needs. Test of hypothesis. *Marine Ecology Progress Series*, 156, 109–120. <https://doi.org/10.3354/meps156109>
- Riisgård, H. U., & Ivarsson, N. M. (1990). The crown-filament pump of the suspension-feeding polychaete *Sabella penicillus*: Filtration, effects of temperature, and energy cost. *Marine Ecology Progress Series*, 62(3), 249–257.
- Riisgård, H. U., Larsen, P. S., & Pleissner, D. (2014). Allometric equations for maximum filtration rate in blue mussels *Mytilus edulis* and importance of condition index. *Helgoland Marine Research*, 68(1), 193–198.
- Riisgård, H. U., & Møhlenberg, F. (1979). An improved automatic recording apparatus for determining the filtration rate of *Mytilus edulis* as a function of size and algal concentration. *Marine Biology*, 52(1), 61–67. <https://doi.org/10.1007/BF00386858>
- Riisgård, H. U., Thomassen, S., Jakobsen, H., Weeks, J. M., & Larsen, P. S. (1993). Suspension feeding in marine sponges *Halichondria panicea* and *Haliclona urceolus*: Effects of temperature on filtration rate and energy cost of pumping. *Marine Ecology Progress Series*, 96(2), 177–188.
- Rodgers, K. L., Rees, T. a. V., & Shears, N. T. (2015). A novel system for measuring in situ rates of photosynthesis and respiration of kelp. *Marine Ecology Progress Series*, 528, 101–115. <https://doi.org/10.3354/meps11273>



Data Sources: References

EFPREDICT R Package

- Rosenberg, G., & Ramus, J. (1982). Ecological Growth Strategies in the Seaweeds *Gracilaria foliifera* (Rhodophyceae) and *Ulva* sp. (Chlorophyceae): Photosynthesis and Antenna Composition. *Marine Ecology Progress Series*, 8(3), 233–241.
- Rosenberg, G., & Ramus, J. (1984). Uptake of inorganic nitrogen and seaweed surface area: Volume ratios. *Aquatic Botany*, 19(1), 65–72. [https://doi.org/10.1016/0304-3770\(84\)90008-1](https://doi.org/10.1016/0304-3770(84)90008-1)
- Sabourin, T. D., & Stickle, W. B. (1981). Effects of salinity on respiration and nitrogen excretion in two species of echinoderms. *Marine Biology*, 65(1), 91–99. <https://doi.org/10.1007/BF00397072>
- Sadok, S., Uglow, R. F., & Haswell, S. J. (1999). Some aspects of nitrogen metabolism in *Mytilus edulis*: Effects of aerial exposure. *Marine Biology*, 135(2), 297–305. <https://doi.org/10.1007/s002270050627>
- Sassaman, C., & Mangum, C. P. (1970). Patterns of temperature adaptation in North American Atlantic coastal actinians. *Marine Biology*, 7(2), 123–130. <https://doi.org/10.1007/BF00354915>
- Savina, M., & Pouvreau, S. (2004). A comparative ecophysiological study of two infaunal filter-feeding bivalves: *Paphia rhomboïdes* and *Glycymeris glycymeris*. *Aquaculture*, 239(1), 289–306. <https://doi.org/10.1016/j.aquaculture.2004.05.029>
- Segelken-Voigt, A., Miller, G. M., & Gerlach, G. (2018). Shell disease in Crangon crangon (Linnaeus, 1758): The interaction of temperature and stress response. *Journal of Experimental Marine Biology and Ecology*, 500, 105–111. <https://doi.org/10.1016/j.jembe.2017.12.017>
- Shirley, T. C., & Stickle, W. B. (1982). Responses of *Leptasterias hexactis* (Echinodermata: Asteroidea) to low salinity. *Marine Biology*, 69(2), 155–163. <https://doi.org/10.1007/BF00396895>
- Shumway, S. E. (1978a). Activity and respiration in the anemone, *Metridium senile* (L.) exposed to salinity fluctuations. *Journal of Experimental Marine Biology and Ecology*, 33(1), 85–92. [https://doi.org/10.1016/0022-0981\(78\)90044-8](https://doi.org/10.1016/0022-0981(78)90044-8)
- Shumway, S. E. (1978b). Respiration, pumping activity and heart rate in *Ciona intestinalis* exposed to fluctuating salinities. *Marine Biology*, 48(3), 235–242. <https://doi.org/10.1007/BF00397150>
- Shumway, S. E., Bogdanowicz, C., & Dean, D. (1988). Oxygen consumption and feeding rates of the sabellid polychaete, *Myxicola infundibulum* (Renier). *Comparative Biochemistry and Physiology Part A: Physiology*, 90(3), 425–428. [https://doi.org/10.1016/0300-9629\(88\)90213-7](https://doi.org/10.1016/0300-9629(88)90213-7)
- Skene, K. R. (2004). Key differences in photosynthetic characteristics of nine species of intertidal macroalgae are related to their position on the shore. *Canadian Journal of Botany*, 82(2), 177–184.
- Skene, K. R., & Raven, J. A. (1998). Photosynthetic characteristics of nine species of marine macroalgae on the east coast of Scotland in relation to the intertidal zone in which they occur. *Botanical Journal of Scotland*, 50(1), 55–62. <https://doi.org/10.1080/03746609808684903>
- Sma, R. F., & Baggaley, A. (1976). Rate of excretion of ammonia by the hard clam *Mercenaria mercenaria* and the American oyster *Crassostrea virginica*. *Marine Biology*, 36(3), 251–258. <https://doi.org/10.1007/BF00389286>
- Smaal, A. C., Vonck, A., & Bakker, M. (1997). Seasonal variation in physiological energetics of *Mytilus edulis* and *Cerastoderma edule* of different size classes. *Journal of the Marine Biological Association of the United Kingdom*,



Data Sources: References

EFPREDICT R Package

77(3), 817–838.

Spaargaren, D. H. (1982). The ammonium excretion of the shore crab, *carcinus maenas*, in relation to environmental osmotic conditions. *Netherlands Journal of Sea Research*, 15(2), 273–283. [https://doi.org/10.1016/0077-7579\(82\)90008-4](https://doi.org/10.1016/0077-7579(82)90008-4)

Stickle, W. B., & Sabourin, T. D. (1979). Effects of salinity on the respiration and heart rate of the common mussel, *Mytilus edulis* L., and the black chiton, *Katherina tunicata* (Wood). *Journal of Experimental Marine Biology and Ecology*, 41(3), 257–268. [https://doi.org/10.1016/0022-0981\(79\)90135-7](https://doi.org/10.1016/0022-0981(79)90135-7)

Strohmeier, T., Strand, Ø., & Cranford, P. (2009). Clearance rates of the great scallop (*Pecten maximus*) and blue mussel (*Mytilus edulis*) at low natural seston concentrations. *Marine Biology*, 156(9), 1781–1795. <https://doi.org/10.1007/s00227-009-1212-3>

Subandar, A., Petrell, R. J., & Harrison, P. J. (1993). Laminaria culture for reduction of dissolved inorganic nitrogen in salmon farm effluent. *Journal of Applied Phycology*, 5(4), 455–463. <https://doi.org/10.1007/BF02182738>

Sun, K.-M., Li, R., Li, Y., Xin, M., Xiao, J., Wang, Z., Tang, X., & Pang, M. (2015). Responses of *Ulva prolifera* to short-term nutrient enrichment under light and dark conditions. *Estuarine, Coastal and Shelf Science*, 163, 56–62. <https://doi.org/10.1016/j.ecss.2015.03.018>

Tagliarolo, M., Clavier, J., Chauvaud, L., & Grall, J. (2013). Carbon emission associated with respiration and calcification of nine gastropod species from the intertidal rocky shore of Western Europe. *Marine Biology*, 160(11), 2891–2901. <https://doi.org/10.1007/s00227-013-2279-4>

Tagliarolo, M., Clavier, J., Chauvaud, L., Koken, M., & Grall, J. (2012). Metabolism in blue mussel: Intertidal and subtidal beds compared. *Aquatic Biology*, 17(2), 167–180. <https://doi.org/10.3354/ab00464>

Tagliarolo, M., Grall, J., Chauvaud, L., & Clavier, J. (2013). Aerial and underwater metabolism of *Patella vulgata* L.: Comparison of three intertidal levels. *Hydrobiologia*, 702(1), 241–253. <https://doi.org/10.1007/s10750-012-1328-1>

Taylor, E. W., & Butler, P. J. (1978). Aquatic and aerial respiration in the shore crab, *Carcinus maenas* (L.), acclimated to 15°C. *Journal of Comparative Physiology*, 127(4), 315–323. <https://doi.org/10.1007/BF00738415>

Taylor, R. B., Peek, J. T. A., & Rees, T. A. V. (1998). Scaling of ammonium uptake by seaweeds to surface area:volume ratio:geographical variation and the role of uptake by passive diffusion. *Marine Ecology Progress Series*, 169, 143–148. <https://doi.org/10.3354/meps169143>

Thomassen, S., & Riisgård, H. U. (1995). Growth and energetics of the sponge *Halichondria panicea*. *Marine Ecology Progress Series*, 128(1/3), 239–246.

Thomsen, J., Himmerkus, N., Holland, N., Sartoris, F. J., Bleich, M., & Tresguerres, M. (2016). Ammonia excretion in mytilid mussels is facilitated by ciliary beating. *Journal of Experimental Biology*, 219(15), 2300–2310. <https://doi.org/10.1242/jeb.139550>

Thomsen, J., & Melzner, F. (2010). Moderate seawater acidification does not elicit long-term metabolic depression in the blue mussel *Mytilus edulis*. *Marine Biology*, 157(12), 2667–2676. <https://doi.org/10.1007/s00227-010-1527-0>



Data Sources: References

EFPREDICT R Package

- Tytler, E. M., & Davies, P. S. (1984). Photosynthetic production and respiratory energy expenditure in the anemone *Anemonia sulcata* (Pennant). *Journal of Experimental Marine Biology and Ecology*, 81(1), 73–86. [https://doi.org/10.1016/0022-0981\(84\)90224-7](https://doi.org/10.1016/0022-0981(84)90224-7)
- Van Donk, E., & De Wilde, P. A. W. J. (1981). Oxygen consumption and motile activity of the brown shrimp *Crangon crangon* related to temperature and body size. *Netherlands Journal of Sea Research*, 15(1), 54–64. [https://doi.org/10.1016/0077-7579\(81\)90005-3](https://doi.org/10.1016/0077-7579(81)90005-3)
- Vedel, A., & Riisgård, H. U. (1993). Filter-feeding in the polychaete *Nereis diversicolor*: Growth and bioenergetics. *Marine Ecology-Progress Series*, 100, 145–145.
- Vidondo, B., & Duarte, C. (1995). Seasonal growth of *Codium bursa*, a slow-growing Mediterranean macroalga: in situ experimental evidence of nutrient limitation. *Marine Ecology Progress Series*, 123, 185–191. <https://doi.org/10.3354/meps123185>
- Vinther, H. F., & Holmer, M. (2008). Experimental test of biodeposition and ammonium excretion from blue mussels (*Mytilus edulis*) on eelgrass (*Zostera marina*) performance. *Journal of Experimental Marine Biology and Ecology*, 364(2), 72–79. <https://doi.org/10.1016/j.jembe.2008.07.003>
- von Oertzen, J.-A. (1983). Seasonal respiration changes in *Pomatoschistus microps* and *Palaemon adspersus*: An experimental simulation. *Marine Biology*, 74(1), 95–99. <https://doi.org/10.1007/BF00394280>
- Vopel, K., Thistle, D., & Rosenberg, R. (2003). Effect of the brittle star *Amphiura filiformis* (Amphiuridae, Echinodermata) on oxygen flux into the sediment. *Limnology and Oceanography*, 48(5), 2034–2045. <https://doi.org/10.4319/lo.2003.48.5.2034>
- Wallentinus, I. (1984). Comparisons of nutrient uptake rates for Baltic macroalgae with different thallus morphologies. *Marine Biology*, 80(2), 215–225. <https://doi.org/10.1007/BF02180189>
- Webster, S. K., & Giese, A. C. (1975). Oxygen consumption of the purple sea urchin with special reference to the reproductive cycle. *The Biological Bulletin*, 148(1), 165–180. <https://doi.org/10.2307/1540657>
- Weihrauch, D., Becker, W., Postel, U., Luck-Kopp, S., & Siebers, D. (1999). Potential of active excretion of ammonia in three different haline species of crabs. *Journal of Comparative Physiology B*, 169(1), 25–37. <https://doi.org/10.1007/s003600050190>
- White, K. N., & Walker, G. (1981). Rate of nitrogen excretion by the shore barnacle *Balanus balanoides* (L.). *Comparative Biochemistry and Physiology Part A: Physiology*, 69(3), 389–394. [https://doi.org/10.1016/0300-9629\(81\)92994-7](https://doi.org/10.1016/0300-9629(81)92994-7)
- Widdows, J. (1978). Physiological Indices of Stress in *Mytilus Edulis*. *Journal of the Marine Biological Association of the United Kingdom*, 58(1), 125–142. <https://doi.org/10.1017/S0025315400024450>
- Widdows, J., Donkin, P., Salkeld, P. N., Cleary, J. J., Lowe, D. M., Evans, S. V., & Thomson, P. E. (1984). Relative importance of environmental factors in determining physiological differences between two populations of mussels (*Mytilus edulis*). *Marine Ecology Progress Series*. Oldendorf, 17(1), 33–47.
- Williamson, J. E., & Rees, T. A. V. (1994). Nutritional interaction in an alga-barnacle association. *Oecologia*, 99(1), 16–20. <https://doi.org/10.1007/BF00317078>



Data Sources: References

EFPREDICT R Package

Wright, P. A., Part, P., & Wood, C. M. (1995). Ammonia and urea excretion in the tidepool sculpin (*Oligocottus maculosus*): Sites of excretion, effects of reduced salinity and mechanisms of urea transport. *Fish Physiology and Biochemistry*, 14(2), 111–123. <https://doi.org/10.1007/BF00002455>

Xiao, J., Zhang, X., Gao, C., Jiang, M., Li, R., Wang, Z., Li, Y., Fan, S., & Zhang, X. (2016). Effect of temperature, salinity and irradiance on growth and photosynthesis of *Ulva prolifera*. *Acta Oceanologica Sinica*, 35(10), 114–121. <https://doi.org/10.1007/s13131-016-0891-0>

Yamamoto, K. (1992). Effects of Hypoxia and Water Temperature on Oxygen Consumption in the Starfish, *Asterina pectinifera*. *Aquaculture Science*, 40(3), 269–272.

Zotin, A. A., & Ozernyuk, N. D. (2016). Comparative study of aerial and aquatic respiration in periwinkles *Littorina*. *Nauka i Studia*, 1, 8–18.



