- Continental shelf narrow or wide, can be modified, exposed during ice ages; 200m
- Shelf break
- Continental slope
- Continental rise
- 3000-6000m deep
 - $\circ \ \ \, \text{Abyssal plains}$
 - $\circ~$ Abyssal hills extinct volcanoes
 - Seamounts active volcanoes
 - Guyot Inactive seamounts, shrinking/subsiding





<u>Tsunamis</u>

• Aceh, Indonesia 26th December 2004

Exposure

06 October 2015 14:54

- Amount of waver energy a shore receives
- Important in determining biological communities in the intertidal
- Governed by the location of the shore and prevailing wind direction
- Ballantine (1961) devised scale: 1-8



- Finer sediments
- Lower wave energy

Sediments

08 October 2015 12:00

Sediments and Biota

- Depauperate habitat cobbles, pebbles, and granules
- · Fine sediments very high secondary productivity due to high organic matter
 - Fig. 1.2 Sections through a variety of shores to show distribution of fauna and flora. Rock and boulder shores have attached and mobile organisms on the surface-the epifauna and the epiflora (mostly macroalgae). Shingle (cobbles, pebbles, and granules) has little fauna or flora. Sands have mainly burrowing animals-the infauna-while muds (silts and clays) have infauna, surface angiosperms, and abundant microalgae.



- · Poorly sorted sediments containing a range of different sized particles • Less packing (if fine)
- Well sorted sediments containing similarly sized particles
- Porosity is very important

•



Figure 1 | Principal features of the marine nitrogen cycle. 1, Anammox, involving the generation of N2 from inorganic constituents by autotrophic microbes. 2, Nitrogen fixation. 3, Nitrification. 4, Heterotrophic denitrification, in which N₂ is produced from NO₃⁻ used in microbial respiration of organic substrates; this process also results in the production of NH4 and CO2 (not shown). 5, Dissimilatory nitrate reduction to ammonium (DNRA). NO3, nitrate; NO2, nitrite; N2O, nitrous oxide; NH4, ammonium. The N2-output pathways, 1 and 4, were the subject of Ward and colleagues' study3.

Nitrogen Cycle, OMZs, and the Archaea

0

- Archaea very important in the nitrogen cycle
- Ammonia Oxidising Archaea (AOA)
- Generate hydrazine N₂H₂
- Includes *brocadia*, *kunenia*, *anammoxoglobus*
- Anoxic zones allow removal of N as N₂



Phosphorous

- HPO₃⁻, PO₄³⁻, H₂PO₄⁻, organic phosphates
- HPO₃⁻ most common
- Recycled rapidly
- Phosphate limitation: photoautotrophs release alkaline phosphatases into water
 - Break down organically bound phosphorous

Sulphur

- Some plankton produce dimethylsulphoniopropionate (DMSP)
- DMSP is released from cells and broken down to DMS
 - 1-4% DMS released to atmosphere
 - Cloud condensation nuclei (CCN) oxidised DMS forms clouds

- Cnidarian
 - Cnidocytes in epithelium
 - High internal pressure small thread ejected
 - \circ $\;$ Filaments penetrate, adhere, or entangle prey
- Shore crabs
 - \circ $\,$ Open dog whelks by holding in one claw and crush with bigger
 - Sheltered shore whelks thicker apex crushed
 - \circ $\;$ Exposed shore whelks thinner (fewer shore crabs)
 - Crabs alter behaviour
- Stomatopods
 - Trinocular vision, 16 rods
 - Raptorial (grab), pugilistic (punch) feeding with modified appendages
 - >300,000ft/s² limb extension
 - Cavitation



Position Maintenance and Orientation

03 November 2015 14:14

Macroalgae

- Hydrodynamic
- Flexible stipe and frond
- Undulation reduced sheer stress
- Holdfasts (negative phototaxis)
- Reduced frond area
- Plasticity express different phenotypes depending on environment
 - Wave velocity affects frond size
 - Holdfast higher mass on exposed shores
- Grouping reduces drag

Rocky/Hard-surface adhesion

- Permanent adhesion Barnacle cement glands
 - Mytilidae mussels
 - Byssus threads and adhesion
 - Protein secreted from gland near foot
 - Plaque forms
- Transitory adhesion Gastropods
- Temporary adhesion Echinoderms (strong attachments, fast breaking)

Hydrodynamics - Streamlining

- Muscular feet with mucus
 Adhesive secretions from disk epidermis form thin all evice time
 Adhesive secretions from disk epidermis form thin all evice time
 Reducing drag high energy shores
 Urchin high drag coefficient
 Lower scince the duce drag
 Molunce and lag coefficient
 Move to face prevailing coefficient
- Limpets clamp closer down with increased lifting force (faster water flow = less downward pressure)

Position Maintenance

- <u>Diatoms</u>
 - Nighttime
 - Mucus secretions bind sediment and the diatoms sink
 - Carried offshore by riptides, won't get stranded
 - Daytime
 - Foam disintegrates and diatoms attach to bubbles
 - Kept near shore by surface currents
 - Morning
 - Divide and start secreting mucus
- Bullia gastropod
 - Uses foot as sail catches waves
 - Migrates with tide to feed on jellyfish and bivalves
- Arenicola marina
 - Proboscis probes sediment, anterior anchors
 - Pharynx everted (hydrostatic pressure), proboscis and pharynx dual anchor
 - Proboscis withdrawn, water drawn through sand, loosens
 - Segments elongate to push worm deeper
- Bivalve burrowing Donax

- Boxfish
- No flexion of body
- <u>Rajiform</u>
 - Just fins
 - Rays
 - Extended pectorals



Camouflage

- Transparency
 - Effectiveness increases with increasing depth
 - Requires similar transmission and refractive index to water
 - High water content, regularly arranged tissues, thin, etc.
- Silvering
 - Guanine panels parallel to surface in stacks
- Iridophores reflective cells in squid etc.
- Countershading evolved with bioluminescence on vented surface
- In mesopelagic the light regime varies
 - Chromatophores often cover silvering
- Bathypelagic many organisms red or black
 - Some species change colour as they mature
 - Juveniles in shallow water
- Benthis species unpigmented

Bioluminescence

- Luciferin protein
 - 4 types
 - Oxidised by luciferinase
- Symbiotic or self-generated
 - *Photobacterium sp.*
- <u>Symbiosis</u>
 - Specialised organ
 Light emission must be controlled of e sale. Co.uk
 Uptake of bacteria
 ht organs derived remoderers in gut
 v light organities
 and st common thesise lucifor • Anglerfish, argentinoid fishes, deep-sea cods etc.
 - Problems
 - Light organs derived from occ
 - Few light organ
- Self-gencialed
 - Most common
 - Synthesise luciferin
 - Several hundred isolated photophores
- Functions
 - Locate food
 - Mate attraction
 - Display defence against predators
 - Confusion
 - Sprays of ink etc.
 - Camouflage
 - Match light filtering from surface
 - Indication of unpredictability



Black lichen/blue green/littorin arnacles Mussels Lithotham ed Algal Turf



Stephenson & Stephenson (1949)

How real are zones?

- Clear patterns apparent on rocky shores worldwide
- Or are they?
- Professor Tony Underwood
 - Argues against it
- 3 zones are an over simplification
 - Many distributions overlap
 - Zonation based on conspicuous species, but species not always evenly distributed
 - o Same spatial relationship not always apparent

Drivers of Zonations in the Intertidal

- <u>Physical factors</u>
 - Desiccation and temperature tolerance
 - Physical factors usually set upper limit of zonation
 - <u>Temperature</u>
 - Effect on 50% mortality rate
 - Physiological tolerance determines distribution
 - Desiccation
- Low shore algae very poor coping with desiccation levels of mortality
 High shore persisted
 I factors
- **Biological factors**
- 87 • Competition, and ation supply of propagules
 - Biologi a fotors often set lowe Omite n zonation 3
 - petition
 - Cthalamus barnacles overgrown, uplifted, or crushed by Semibalanus
 - Cthalamus grows slower
 - Cthalamus settles low down, but restricted by Semibalanus
 - Without Semibalanus, Cthalamus persists out of normal zone
 - Predation
 - Bob Payne
 - Lower limit of mussels set by predatory starfish
 - Mussels can persist lower down shore without starfish
 - Keystone predator complex
 - □ Without starfish mussels move lower, outcompeting algae
 - Larvae settlement and mortality
 - Settlement very important
 - Chemical and tactical cues
 - Settle over wide distribution physical stresses etc. restrict due to post-settlement mortality

Damselfish - defend farmed algae

Separating the Mechanisms

- Caging and transplanting experiments to look at sandy substrate bivalve species
- Protothaca closer to surface
- Sanguinolaria and Tresus at same depth
- What drove competition shortage of space or food?
 - Ysed dead individuals to test space
 - Some competition
 - Live individuals to test food and space
 - More competition

Intra-vs. Interspecific Competition

- Enclosures of species in isolation, together, and at different densities
- Higher densities increased mortality and reduced biomass across intraspecific treatments
- Both species same effect at all densities
- Intraspecific greater effect than interspecific for Patella vulgata
- Intra often thought stronger than interspecific
 - Exactly the same resources

Competition and Other Processes

- Nucella not on high shore (whelk)
- Preferentially consumes Semibalanus
 - Decreased competitive effect with predators present
 - Semibalanus doesn't reach carrying capacity, competition low effect

Facilitation

- At least one species benefits, no harm
 <u>Intraspecific competition switch to facilitation</u> otesale.co.uk
 Maine cooler than Rhode Island
 Coasts cooler than log In cooler location soli al y individuals no better an with neighbours

Competition for space

- arm locations lo Peret of olitary barnacles
 - Crowding reduced barnacles body temperature
 - Facilitated survival
- Interspecific competition to facilitation
 - Manipulated cover at high and low shore
 - Relative role of positive and negative effects
 - High shore cleared spots higher stressors
 - Increased temperature
 - Increased desiccation (% water loss from sponges)
 - Recruitment to three treatments
 - Lower on HS than on LS
 - Shore height x canopy cover interaction
 - □ Canopy cover positive effect on high shore
 - Negative or neutral on low shore
 - Survival and growth similar patterns
 - High predation at low shore
 - More likely beneath canopy negative effect
 - Grazers reduced macroalgal abundance below canopy negative effect
 - Positive effects of one species on other becomes more important under harsher conditions

Model Drivers of Community Structure

- Predation more important at low environmental stress
 - Mobile predators restricted to benign environments

Larval Dispersal and Supply-Side Ecology

30 November 2015 13:13

Larval Dispersal

- · Nearly all marine organisms have a period of broad dispersal
 - Planktonic
- · Can last ours to months
 - Longer = more dispersion

Supply-Side Ecology

- · Variation in number of offspring produced, settling, and timing of settlement
- Vary in time and space
- · Supply of propagules and recruitment to adult populations are considered as important as processes such as predation, competition, facilitation, and disturbance
- Most of our knowledge comes from barnacles and mussels, with some tropical fish research Less on algae and other invertebrates

Survival in Plankton

- Zooplankton important trophic link
- \circ $\,$ Larval stages subject to high mortality enormous variation in number of surviving propagules • Environmental factors can influence larval duration
- e.g. increase in temperature shortens larval duration, reduced exposure to predators
- e.g. breeding population of 1000 females produces 1 million eggs during a breeding season
 - Nt (surviving at end of day) = N0 (start no.)xe^{-Rt} (Napier's Constant -instantaneous rate of mortality x larval duration)

		Period of dispersal (t days)		
0	Mortality (R)	18	20	22
	0.76	1,148	251	55
	0.69	3,981	1,000	251
	0.62	13,804	3,981	1,148

 \circ $\,$ 10% change in mortality and period of development leads to large changes in N_t

Settlement and Recruitment

- Some habitats no individuals will settle, others large numbers settle
- · Unlikely to find widely repeated assemblages

Variation in Recruitment and Intensity of Species Interactions: Local Scale

- anation in Recruitment and Intensity of Species Interactions: Local Scale
 Recruitment largely determines adult distribution, abundance patterns, and influences strength of biotic interactions
 Locations with low larval settlement rates generally low adult densities

 Varies within years slightly, more between years based on settlement
 Mortality not density dependent, no competition, low prediction potentic callee effects due to the reducing mating capability)

 Locations with high cutif
- Locations with high settlement have high adul der
 - Vary greatly within years, stight, but years to be the state of t n yea s - at carrying capacity iotic variations
 - Mortality density dep in
 g. *i.i. st*

Variation in Recruitment and Intensity of Species Interactions: Broad Scale

- Upwelling important oceanographic process along many coastlines
 - Western North and South America
 - Western Africa
 - Southern New Zealand
- · Where upwelling is strong larvae are pushed offshore and recruitment is low



- Where upwelling is intermittent larvae are pushed onshore and recruitment is high
- Variation in upwelling influences larval supply and therefore species interactions



difference

Density of bioturbators changed richness, turnover, and structure

- Temporal/spatial=velocity
- Provides measure of the speed with which species will have to move to remain within isolation



- SST and air temperature 1960-2009
- Global VoCC
 - Terrestrial 27.5km/dec
 - Oceanic 21.7km/dec
- 50°S-80°N
 - Terrestrial 27.5km/dec
 - Oceanic 27.4km/dec
- Ocean VoCC 2-7x faster in sub-arctic and tropics



- Distribution and VoCC
 - Correlation with paper data



- Faster VoCC, greater range shifts
- Using real data, VoCC explained >50% of variation