Sample essay questions to help you revise

Below we have provided some example questions you might encounter in a final year exam for a Bachelor of Science Honours degree. You should revise for each question and then allow yourself 90 minutes to write your answer. Ensure you use 10 minutes to plan your essay and compile the key points and examples you want to use.

In the accompanying document we provide the questions again with pointers as to what the content of the essay would cover, but we do not provide a model essay for reasons associated with potential plagarism. Use this document after you have written your essay or essay plan to see if you picked up the points we highlighted.

As the majority of the authors teach in Universities we have based our questions on our collected experience of setting exams. **In addition to reading the advice on 'how to write a good essay', available through the online resources which accompany this book**, it is patently clear that a good essay will be evidenced with lots of relevant examples to illustrate the statements you make. Remember to **ask yourself the key questions outlined in the essay advice** (what? Where? When? Who? How? etc.). Examples will be taken from the primary literature and will not be grazed from Wikipedia! Although the questions below are specific to certain chapters, good answers would necessarily draw on information in other chapters, particularly the information in Chapters 1 to 4 and Chapter 15 to 18. We have not set a specific question for Chapter 1 as it should be reflected in the answers to the majority of questions below.

Chapter 2

2.1 Factors influencing phytoplankton productivity are many and varied. Discuss how light and inorganic nutrient supply control phytoplankton growth.

A question such as this general one needs careful consideration, since it is very easy to get side-tracked onto tangential issues. A good policy would be to say that since the question asks for two factors to be discussed, then 50% of the answer should be dedicated to the light aspect, and 50% to the nutrient part.

Regarding light, there should be a discussion of how light penetrates waters and how water colour can alter the light climate experienced by phytoplankton at different depths. This can lead on to presenting the photosynthesis vs. irradiance diagram and discussing compensation points, saturating light levels and a brief mention of photoinhibition. Naturally this then leads on to the discussion of critical depth theory and how mixed water depth and light penetration combine to ensure that phytoplankton communities are illuminated enough to enable growth to proceed.

When considering the nutrient aspect of the question, it would be best to break the answer down into macro- and micronutrients. As examples of key nutrients it may be the best option to focus on nitrogen (nitrate, ammonium and nitrite) and phosphorus. However, some mention needs to be made about silicate for diatom growth. As an example of trace nutrient limitation to phytoplankton growth iron could be used. The key concepts to discuss for all of the above nutrients are the sources and cycling of nutrients within the marine system, and certainly for nitrogen this could be greatly helped by a diagram to show the interactions between the different nitrogen pools in marine systems.

2.2 Seaweeds are conspicuous primary producers in marine and estuarine systems. Discuss their importance in relation to other primary producers in marine and estuarine systems.

A natural starting point for this answer is to point out how productive seaweeds are compared to terrestrial crop systems. However, the key point is then to illustrate how seaweeds only grow down to limited water depths on coasts, and therefore on an area basis their productivity is very small compared to the huge expanses of ocean where phytoplankton growth can occur. There would also need to be a comparison of seaweed primary production with seagrass and mangrove systems (Chapter 10), although again even these are relatively unimportant compared with estimates of phytoplankton productivity. Included some facts or figures to illustrate these points would be helpful.

However, it is important to point out that in particular habitats, seaweed growth is the dominant form of primary production: intertidal shores of rocky shores and estuaries, shallow subtidal benthic communities where light penetrates. This is especially true where nutrient runoff encourages the growth of opportunistic swift growing species. Calcareous macroalgae are also very important in many coral reef systems (Chapter 11).

Where they do grow, seaweeds are important food sources and provide infrastructure that supports many invertebrate species, larvae and juveniles of many vertebrate species. They are also an important source of carbon that is exported to other parts of the intertidal and subtidal ecosystem.

The thrust of the answer would be that although small in terms of overall marine primary production (and therefore global productivity), seaweed primary producers are rather fundamental for hugely important marine ecosystems.

Chapter 3

3.1 Multiple factors regulate growth in the oceanic microbial food webs. Present and discuss the two basic categories of controlling factors.

The answer should include two equally important main categories, resource limitation and grazing control, presented in a balanced way. Discussion on resource limitation (bottom up-control) should include a general description of the control mechanism, i.e. shortage of essential resources (as organic carbon or nutrients) limiting the growth of bacterial populations. The two basic limitation principles – Liebig's law of minimum- referring to scarcity of resources that place an upper limit on the **standing biomass** of bacteria, and Blackman limitation- referring to limitation of the **metabolism or growth rate** of bacteria. Discussion would then evolve to include multiple limiting factors and resource competition occurring in realistic oceanic microbial food webs.

Discussion on grazing and mortality control (top down-control) should include again a description of the control mechanism, i.e. organisms at higher trophic levels controlling the abundance of organisms at lower trophic levels by preying or grazing on them (note also the similarity to pelagic systems in Chapter 7). In addition, mortality caused by viruses belongs to this control category. Trophic cascades, where predation on higher trophic level (e.g. ciliate grazing on flagellates) releases predation pressure on lower trophic level (e.g. flagellate grazing on bacteria) and leads to increase in bacterial standing biomass is also a central concept to be included. It would be a good option to include mechanisms that complicate trophic cascades such as; prey-size selection and predation avoidance by morphological changes, and Lotka-Volterra limit cycle oscillations (where abundance of predator and prey match each other in rapid sequence).

3.2 Planktonic microbial food webs in temperate seas undergo a seasonal cycle with four distinct phases. Describe the seasonal cycle of production and consumption and discuss the causing factors and features of each major phase.

The seasonal changes in solar angle and subsequent changes in the solar energy entering the oceans needs to be identified as an ultimate underlying factor for seasonal cycle of production and consumption in temperate seas. This should include the effects mediated by thermal stratification of the water column and wind mixing which regulate the amount of light entering the productive layer as well as nutrient flux from deeper water layers. Four phases described below should be presented in the answer on a general level.

Description of **Phase I** – the initiation and growth of the phytoplankton bloom- should start with the onset of thermal stratification with shallowing of the mixed layer. The bloom is dominated by large diatoms, who are favoured by high levels of nutrients present in the water. This is a period of net community production that ends when nutrients become depleted in the water and algal growth slows down. Slowing algal growth due to onset of resource limitation is the main causative factor leading to the next phase.

Description of **Phase II** – the demise of spring bloom- should include the changes in overall community metabolism from net autotrophic towards net heterotrophic as heterotrophic organisms, both grazers and decomposers, are favoured by previously produced algal biomass still present in the water. The heterotrophic biomass increases and algal community changes towards smaller species as nutrients become scarce. This is a transitional phase that leads to the next, more stable phase.

Phase III – the mid-summer recycling period- should be defined as a phase of closely coupled metabolism and a food web tightly controlled by grazing. The reason for this is a strong thermal stratification preventing new nutrients entering the productive layer from beneath and leading to a tightly controlled recycling of nutrients. Small species are favoured in this phase and important organism groups have comparable growth rates and food web is tightly grazing controlled. The system is self-sustaining and resembles the low-latitude oligotrophic planktonic communities. The Phase III ends by the breakdown of the thermocline typically accompanied by a small autumn bloom of planktonic algae.

The description of **Phase IV**- the final regeneration of nutrients- should include again a mention of a shift from autotrophic to heterotrophic community metabolism. Phytoplankton activity decreases due to declining light conditions and deepening of the mixed layer. Heterotrophic organisms, especially bacteria, continue their growth on dissolved and particulate organic matter still present in the water. As they decompose organic matter, they also regenerate plant nutrients, eventually reinstating the circumstances that existed at the onset of the spring bloom.

This answer would be informed better with the use of diagrams to augment any text description of the processes above.

Chapter 4

4.1. How does bottom trawling affect the biomass, secondary production, P:B ratios and body size distribution of benthic invertebrate communities?

Bottom trawls that are dragged over the seabed cause mortality of benthic invertebrates and reduces biomass and secondary production of benthic invertebrates communities. A shift in dominance from large bodied to small bodied animals will occur because the 'faster' life history of small bodied animals makes them less sensitive to the additional mortality that is caused by bottom trawling. Use specific examples, e.g. polychaete worms and small bivalve species and contrast these with longer-lived species like cold water corals, maerl (calcareous algae), long-lived slow growing clams (e.g. quahogs). Smaller organisms have a higher P:B ratio and therefore the P:B ratio will increase. This means that the reduction in production is less pronounced than the reduction in biomass.

4.2. What ecosystems and groups of organisms have the highest amounts of secondary production and why? Is it possible to increase and decrease secondary production in an ecosystem? How, and why or why not?

Organisms at low trophic levels, such as zooplankton and filter feeding benthos generally have the highest secondary production, as the loss of energy through the low transfer efficiency between trophic levels has had less impact at low trophic levels. Areas with a high primary production, such as temperate shelf seas such as the North Sea are most productive and for that reason support considerable fisheries (Chapter 13). Secondary production can be increased through moderate eutrophication, e.g. from agricultural run-off containing nutrients from fertilizers, which can result in higher levels of primary production. The removal of top-predators in top-down controlled ecosystems is also likely to result in a higher production at lower trophic levels (see Chapter 7). Secondary production will decrease in response to fishing and excessive eutrophication. Both reduce the biomass of the organisms in the ecosystem (eutrophication through anoxia, fishing through targeted removal, incidental by-catch and other damage by fishing gears) and therefore their potential to produce new biomass is impaired.

Chapter 5

5.1 Explain how the physico-chemical environment varies as you move along an estuary from river to sea. How does this influence patterns of organism distribution within the estuary?

There are two key factors involved: the increase in salinity from 0 to 34 and how conditions at any one location can be extremely variable due to tidal movement. This variability is greatest in the mid-estuary, where stresses due to large diurnal changes in salinity are compounded by the presence of extensive mudbanks in this region. These mudbanks form due to the combination of slower water movement as tide and river meet plus the reduced salinity resulting in more sediment falling out of the water column. Sedimentation is also associated with flocculation of organic particles and hence is rich in organic matter, so dissolved oxygen also tends to be at a minimum in the mid estuary due to increased biological oxygen demand fuelled by organic matter.

Overall organism diversity responds to the level of variability in the estuarine environment, and thus stress. Consequently, there are higher diversity levels at each end of the estuary compared with the middle (Remane diagram); you can also directly relate the number of species to salinity range. At the river end, diversity tends to decrease quickly as freshwater species tend to be comparatively intolerant of salinity changes. The diversity decrease from sea to estuary tends to be less steep as some marine species (e.g. *Hediste*) are able to tolerate the harsh conditions in the middle of the estuary. At this point, there are a few specialists that are often not found elsewhere; these have a range of adaptations for survival. Due to the high food supply in mid estuary, there tends to be very high abundances of the few species able to survive in mudflats. A good answer would highlight that diversity patterns vary between types of organism (e.g. algae and invertebrate species).

5.2 Why are estuaries considered important for commercial fish stocks? Discuss the environmental factors influencing fish movement in estuaries and what tools can be used to assess whether a fish caught at sea has spent some of its life in an estuarine ecosystem.

Estuaries have three main values to commercial fish stocks, each of which could be explored in an answer. Most importantly temperate estuaries, in particular, are a nursery ground for 0+ and 1+ fish of a range of commercial marine species, juveniles spending this important stage feeding and growing in estuarine systems before moving offshore and recruiting to the coastal stock. Good answers may also bring in migrating fish, such as salmon (anadromous), eels (catadromous), and amphidromous gobies, that move through estuaries and some species, such as flounder, which can spend most of their life in estuaries.

Many fish juveniles show seasonal movement in and out of estuaries to exploit the conditions at a certain time of the year, particularly moving in during winter, whilst other species (such as grey mullet) migrate in and out with the tide, thus avoiding lower salinity conditions. Modelling work on long-term fish movement has revealed that salinity seems to be surprisingly unimportant as a cue that fish are using for seasonal movement, with temperature changes appearing to be the most likely variable affecting these migrations. However, human impact can affect this, with low oxygen in particular being a major barrier to fish accessing estuaries. In the long term, it has been suggested that the temperature differential between the open sea and estuary may be a major driver for fish movement between years, with this differential being affected by climatic variation (see also Chapter 17).

We can assess whether fish have spent their early year(s) in estuarine/low salinity conditions by analysing the chemistry of their otoliths (ear bones). When growing, these hard calcareous structures take up minerals from the surrounding water. As the mineral composition of water varies with salinity, this is reflected in levels of certain metals within the otolith. In particular, strontium ratios have been used to detect whether fish have been in low salinity water for a prolonged period of time. By analysing the otolith in fine detail, samples can be taken from the centre of the otolith (i.e. the first part to be laid down when the fish was young) and compared with the outside when the fish was older (otoliths can have age rings like trees) to assess whether the fish was in low salinity water as a juvenile.

Chapter 6

6.1 Describe why and how experiments in intertidal systems have offered insight into ecology more generally

You should describe some of the key features of intertidal systems, in particular the broad environmental gradient that occurs over a small spatial scale and the fact that you can see exactly what you are doing at low tide which makes experimental work much easier (and more accurate) than doing experiments in the subtidal environment. The latter has implications for the precision of the results that you acquire at the end of your experiment and enables you to design and lay out an experiment properly. You may wish to cover some of the key features of a well-designed experiment (see also Chapter 15 where we discuss experimental replication). Having focused on experimental design, you might want to reflect that some of the seminal papers (e.g. Paine's early work in the 1960s and Hawkins in the 1980s) were flawed in their experimental design and explain why, but how the results seemed so clear that they were not challenged. These seminal experiments should be described, the key organisms and biological interactions in the experiments and give examples from different parts of the world, thinking about similarities and differences that might be observed. The ubiquity of these patterns across the globe is important and helps to underline the importance of key components such as grazers and predators. A focus on soft sediment shores would lead to a discussion about how the relatively simple assemblage enabled a foodweb type analysis and sequence of controlled experiments in the Ythan Estuary. Describe some of these experiments and the areas where questions remain. Finally conclude with a discussion about what insights have been gained from these systems in terms of the biodiversity ecosystem function debate.

Chapter 7

7.1 Describe the 'paradox of the plankton', and explain why modern sampling techniques are serving to dispel it.

The paradox of the plankton questions how an apparently-homogenous pelagic open sea can accommodate such a high diversity of planktonic species. Competitive exclusion usually serves to limit the number of species in a single niche because evolution leads to the dominance of a single species that out competes others. The ocean is in fact far from homogenous. It would be good to emphasise the range of different processes that divide the pelagic system into different 'habitats'. The pelagic system is patchy over a very large range of time and space (vertical and horizontal) scales, and this patchiness offers a large number of diverse habitats. Microlayers that are vertically discrete (perhaps as thin as tens of cm) but horizontally extensive are amongst the most recently detected heterogeneity, and have been revealed by instruments capable of very fine vertical resolution. Microlayers may represent separate habitats, and explain in part vertical segregation of species / size classes, and foster diversity. Spend time in the essay considering the different sampling techniques (from CTD profilers to AUVs and acoustic sampling) and explain the different insights that these provide of the 3D environmental of the pelagic realm.

Chapter 8

8.1 Describe the importance of scale considerations in understanding the impact of natural disturbance in marine benthic shelf sea communities

The essay would start with a focus on the scale at which different geological and environmental factors determine the key physical attributes of benthic habitat. A consideration of the age of continental shelf systems on geological timescales, the formation of underlying bed strata (glacial deposits, finer sediments) and the physical processes that structure these physical components. Think on scales of 10000 years, 10 years, 1 year, and 24 h. The scale at which physical processes influence the overlying water mass and how this modifies bed morphology would be important. Physical features such as ROFIs, fronts, stratification, currents and waves. Once these issues have been considered the essay would move on to consider the timescale over which these processes operate and how biological processes (predation, habitat reworking) influence these systems and at what spatial and temporal scales. The above should be punctuated with reference to key paradigms such as the intermediate disturbance hypothesis and the Pearson Rosenberg model (using a variety of examples), and would use conceptual diagrams to show the interaction between spatial and temporal scales in relation to recoverability.

8.2 Discuss how the changing climate is likely to affect continental shelf systems around the world

A good answer would use some of the information from the answer above, but integrate it in the context of Longhurst's characterisation of different types of shelf system around the world (e.g. polar vs cold temperate etc). For each of these systems it would be necessary to consider 'what would happen' if, for example, all the ice is removed from the North Pole. A consideration of the information in Chapter 15 is therefore important in answering this question. From understanding the key changes in the physical drivers it would be possible to infer the type of changes likely to be observed in different parts of the world. We know for example that rainfall will increase in its intensity and frequency in some localities but not in others, hence discharge into the adjacent oceans will vary in terms of the extent to which this changes from one place to another (the deserts will get drier while temperate systems may become wetter). Consider also changes to the physical system that applies to all regions, storminess, its intensity and frequency will affect shallow areas more than deeper offshore areas. This will also affect stratification and hence primary production with consequences for the associated systems that depend upon that production.

Chapter 9

9.1 Discuss what food supplies are available to deep-sea organisms and the mechanisms they use to make the most of the food available

Food supplies to the whole of the deep sea come from two sources: material sinking down from the euphotic zone and bacterial primary production at vents on the seabed. The vast majority of the deep sea has, however, to rely on export of material from the plankton to the seabed. This organic material can be in two main forms: large food falls (e.g. fish/whale carcasses) and amorphous aggregates (Particulate Organic Matter – POM), or marine “snow”, a combination of dead plankton, zooplankton exoskeleton moults and faeces that escapes the surface layers and sinks to the seabed. In temperate areas this input can be seasonal. Due to the low food levels and unpredictable nature of large food falls, scavenging organisms have to be able to make the most of any arriving food. Many lay comparatively dormant, emerging when they sense carrion and gorging on the available food. Examples are hagfish and “giant” amphipods, the latter able to consume up to 75% of body weight in one go. Some deep-sea organisms (e.g. bivalves) have even evolved to feed on wood debris that sinks to the sea floor.

Hydrothermal vent systems occur where underground magma heats up water, which vents out of the seabed at extreme temperatures. This water is mineral rich and supports bacterial primary production through chemosynthesis. Consequently this production fuels the highest biomass assemblages to be found in the deep ocean, with many vent organisms having developed a symbiotic relationship with the chemosynthetic bacteria. Key examples are deep sea mussels, etc. *Bathymodiolus* and giant tube worms, e.g. *Riftia.* These 2m long worms are highly modified with no mouth or gut, but contain vast numbers of bacteria within their body cavity – up to 50% of their body weight. The worm takes up organic carbon from the bacteria, using its tentacles to uptake other nutrients for growth and mineral compounds to fuel the bacterial production. A good answer would address the special metabolism of vent organisms.

9.2 Review the environmental conditions experienced by an organism living on the abyssal plain and conclude which of these has the most limiting effect on deep-sea assemblages.

The abyssal region of the deep sea is generally around 5000 m below the surface and is the largest benthic habitat in the world. Whilst the idea of a “plain” suggests an expansive flat topography, more recent surveying suggests that underwater hills and seamounts are more common than previously thought, although most of the deep sea is experiencing fairy constant conditions across the main ocean floor. No light penetrates to the sea bed at these depths, there being not enough light for vision below 1000 m. Consequently the abyss is in total darkness save bioluminescence; there are therefore no photosynthetic organisms in the deep sea. Temperature is comparatively constant and cold (2°C) across the globe, with the coldest recorded water below Antarctica and warm deep-sea regions found in enclosed seas such as the Mediterranean and Red Sea. Water movement at depth is maintained by several currents, predominantly the oceanic conveyor current which enables a continual supply of “fresh” (in terms of oxygenation and nutrients) water, thus maintaining dissolved oxygen levels at around 5 mg/l. Some “dead zone” areas of the deep-sea lack such currents and thus have low oxygen and little life, but most of the deep sea is not limited by oxygen. The most notable and predictable variable is hydrostatic pressure: at the abyssal plain the pressure is 500 times that at the surface. Whilst there are great changes in pressure as you move through the water column, organisms on the seabed are adapted to a constant high pressure, although this can slow the rate at which enzymes work, for example. Combined with the cold temperature it means that many deep sea organisms move little, or quite slowly.

None of these factors vary greatly across the sea floor, and so are not particularly limiting. However, most of the deep sea floor is composed of very fine mud up to 1000 m deep, which can clog feeding and reproductive structures and provide a difficult substratum for settlement and locomotion. The composition of the mud varies depending on depth and the type of planktonic production in the surface layers above. The fine sediment therefore could be seen as the most difficult of the physico-chemical variables to deal with. The most important limiting factor, however, is biological – food supply. Only 1-3% of surface primary production reaches the seabed, so the vast majority of the deep-sea ecosystem has to rely on this low level of available organic carbon. Consequently, the deep sea is characterised by low abundances of organisms compared to shallower water, reflecting the overall low level of food available. Food supply can be even lower beneath oligotrophic waters (e.g. centres of oceanic gyres), with resulting further decreases in benthic biomass. In other regions food supply can be seasonal, reflecting blooms at the surface and providing a seasonal cue in the deep sea that was though unlikely due to the constant nature of the other environmental variables.

Chapter 10

10.1 Discuss the main problems faced by mangroves trying to survive in the marine environment. What adaptations do the trees have enabling them to deal with these problems?

Mangroves tend to grow around the fringes of tropical estuaries and lagoons, as well as in the intertidal regions of tropical coasts. Here they face two key problems associated with the generally muddy substrate they inhabit: waterlogged sediment and increased salt levels, both of which would be fatal for most tree species.

The major problem resulting from waterlogged sediment is the issue of getting oxygen to the roots, particularly as mud tends to be anoxic below the surface layer. Mangroves have a range of root adaptations to deal with this, allowing part of the root structure to reach the surface of the mud, obtain oxygen through pores called lenticles and pass it back to the roots. Examples (to expand on) include: aerial roots in *Rhizophora,* knee roots in *Laguncularia* and snorkel-like pneumatophores in *Avicennia.* Dealing with the salt in the water is more problematic as it reduces the osmotic difference between the root and the medium making it much more difficult to take up water. The salt also disrupts cellular mechanisms in trees and so could be fatal: mangroves are tolerant of increased salt levels, but either prevent salt coming in through the roots or have excretion mechanisms (e.g. dumping salt in leaves and shedding the leaves). As mangroves take up water less readily than other plants, they tend to have a much higher root biomass to compensate and the proportion of root/above ground biomass increases with increasing salinity. They also have to retain as much water as possible, thus affecting the transpiration mechanisms for temperature control used by many other plants. Dealing with salt is also physiologically costly, one of the reasons mangroves are only found in the tropics where there is enough year-round light energy for continual photosynthesis.

10.2 How do changes to the physical structure of seagrass beds affect the organisms living amongst the seagrass?

The physical structure of seagrass meadows can vary at a range of scales, such as changes in the structural complexity of the plants themselves, variations in the density of seagrass shoots and fragmentation of beds into patches of different sizes. All have the potential to impact the organisms and the ecological processes within the seagrass beds and there are many examples to illustrate these points in a good answer.

There is much evidence that seagrass beds have a much higher diversity and faunal abundance than surrounding bare sediments, but further studies have also demonstrated that habitat structural complexity within seagrass beds can be related to the diversity and abundance of organisms present. This fits with the theory that the more structurally complex a habitat, the more niches are available and thus the higher the number of species that can be supported (similar to coral reefs, mangrove roots, etc.). At this scale complexity may, however, not be the only important factor as total seagrass biomass (i.e. the area of habitat available) may be the driving force behind increased diversity. Density of a bed can also influence the associated faunal assemblage. For example, denser beds can accumulate larger numbers of organisms than sparse beds, perhaps demonstrating a refuge from predation as larger predators are potentially less efficient in the dense habitat. It has also been demonstrated that edges of beds are different from centres of beds, again perhaps due to predation impact on the margins. Predation is one process that can be affected by fragmentation of the bed into patches, resulting in an increased edge area available for access by predators. Fragmentation can reduce the overall area of the bed, potentially reducing the area of cover for larger species and restricting movement of organisms that would have to cross bare ground to move between patches. Studies have demonstrated that continuous beds have different assemblages to fragmented patches, with survivorship of some species being lower in patches compared with larger bed areas.

Chapter 11

11.1 Assess the vulnerability of coral reef animals to climate-related coral bleaching.

An answer would consider the nature of coral bleaching events, the types of corals most affected, and factors affecting their recovery. Frame this some consideration of the biogeographic (present day) context of reefs (northerly and southerly limits, hotspot areas). Review knowledge of the direct dependence of fish and other mobile reef organisms on living corals as a source of food or habitat giving some examples that illustrate these relationships. Review the role of corals as ecosystem engineers building important habitat for fish and other mobile coral reef species. Look at the issues of alternative stable states and in particular think about the concept of hysteresis. Consider the issue of connectivity between reefs for larger ecological issues i.e. could the wider coral system break down if critical stepping-stone reefs demise. Consider different time scales over which biodiversity might be lost on coral reefs which do not recover from coral bleaching events. Give specific examples of studies that illustrate these ideas.

Chapter 12

12.1 Discuss how Antarctic sea ice assemblages have an important role for the Southern Ocean “ecosystem”.

For a good answer to this question, it is important to consider that sea ice assemblages in the Southern ocean are generally present for 4 to 6 months of the year and that for the rest of the time the Southern Ocean is largely ice-free. Even when the ice is at its maximum extent much of the SO is ice-free. It would be important to emphasise at an early stage the relative proportions of sea ice primary production compared with the overall primary production of the Southern Ocean.

Accordingly, there are two main facets that the answer should include: 1) The role of the ice assemblages as a food source for other organisms and, 2) what happens to the assemblages once the ice melts in the austral spring/summer.

The natural way to illustrate (1) is to talk about the importance of sea ice organisms in sustaining winter populations of krill, and how krill in turn are a key food resource for birds, seals and whales. It would be a good idea to show how krill recruitment is associated with previous sea ice history and link this to the studies that discuss about the more direct observations of krill distribution under sea ice. It would then be a natural point to speculate about what would happen to krill populations if sea ice was not present as is likely to happen with climate warming.

When considering (2) it is necessary to talk about the pulse of organic matter released from melting sea ice and what proportion of this goes to seeding ice edge blooms and/or what sinks to the seafloor. The latter is an important food source for many sessile benthic communities, and so this part of the answer could lead on to a discussion about whether or not food supply to these communities is restricted to pulses, or whether other processes such as sediment resuspension mean that benthic systems experience a more continuous food supply.

12.2 With the permanent sea ice cover in the Arctic Ocean thought to be lost sometime within the next 100 years, speculate about the consequences for the Arctic marine productivity.

The danger of this sort of question is that there is no correct answer and so there can be the scope to develop vague arguments without really getting to grips with the problem. However, with some careful planning and disciplined writing, such questions are great opportunities to be creative and really show what you know.

There has to be a brief introduction to the predictions of ice decline. It would be important to stress that the Arctic is not becoming ice free, but rather the sea ice may disappear for part of the summer. Therefore, the annual cycle of sea ice may become closer to what is currently known for the Southern Ocean. It is important to consider the consequences for both ice extent and thickness.

After setting the scene, it would be important to address issues such as the consequences of such change for primary production, both in the ice and in the water column with changed ice conditions. This should invoke some discussion about the changed physical characteristics of the water column in the Arctic due to reduced ice cover, as well as mentioning possible changes in freshwater inputs into the Arctic, particularly from adjacent land-masses. The effects of change on nutrient supply should be introduced here.

The changes in primary production will have cascading effects on zooplankton, vertebrate species and the whole ecosystem. This is where the real creativity will come in by portraying a number of possible scenarios. It may be an idea to highlight open water systems compared with shallow coastal systems. These should of course extend from the primary producers to top predators.

Another interesting facet that could be included is of course the introduction into Arctic waters of species that have up to now been excluded. How will such species change the system? Of course the socio-economic aspects of change to the Arctic ocean cannot be ignored (increasing hydrocarbon exploitation, fisheries, mineral extraction from the sea floor etc), and a general conclusion using this theme may be a good way to end such a discussion.

Chapter 13

13.1 Why do fisheries need to be assessed and managed? What are reference points and why are they used to support management?

Unregulated fisheries are rarely sustainable. Fisheries need to be managed to meet a range of objectives that provide long-term benefits to society. A good understanding of the population biology of fished species is needed to predict the levels of catch that can be taken from fisheries, but without compromising catches in future years. Reference points are used to guide management and may, for example, provide targets for stock biomass or fishing mortality that are sustainable or avoid serious and irreversible harm to a fish stock. The status of the stock or the rate of fishing in relation to a reference point provides guidance on the management action to take in the fishery.

A good essay would describe the reasons why unregulated fisheries are not sustainable and emphasise that they rarely provide long-term social and economic benefits to society providing specific examples to illustrate these points (e.g. Grand Banks cod example). It may also describe the evolution of an unregulated fishery with a figure to help illustrate the timing of different responses of the system. The essay would describe how assessment is needed to describe the status a fish stock and its predicted response to future management actions. Students would be expected to define reference points and to provide some examples, which ideally include examples from the published literature in addition to those in the book. A good essay would explain that the relationship between the assessed biomass or fishing mortality and the corresponding reference point provides guidance on the management action to take.

13.2 Describe the main impacts of fishing on the environment and how might managers ensure that they are sustainable?

Fishing can have impacts on fish communities, birds and marine mammals and reptiles and seabed habitats. These are often unsustainable and managers thus focus on reducing impacts, often by adopting an ecosystem approach to fisheries management.

A good essay would describe the main impacts of fishing (e.g. on fish communities, birds and marine mammals and seabed habitats) in a systematic and balanced way. It would discuss the management issues that result from fishing impacts, such as the failure to meet objectives or policies set by management agencies and may describe the reasons why it is hard to achieve sustainability. Students would be expected to refer to the ecosystem approach to fisheries management as an approach that helps to ensure fishing impacts are sustainable and would ideally define this approach and state its purpose. A good essay would include original examples from the published literature in addition to those presented in the book (perhaps also refer to examples in Chapter 16 and 18).

Chapter 14

14.1 Describe the environmental impacts associated with marine aquaculture and how these might be mitigated in the future

The essay would address the issue of the introduction of man-made structures, the use of artificial feeds, the use of chemical and medicinal treatments, the costs of energy consumption and the possible introduction of exotic species, increased parasitism and the issue of genetic modification through escapees, the gold rush in shrimp farming and ensuing environmental damage to mangrove forests and water pollution issues. Each of the above headings would be dealt with in turn outlining the problem and associated community or organismal response. Mitigations should include various management practices, for example, to reduce seabed impacts, the use of farm rotation to allow seabed recovery, or the use of novel solutions such as cleaner fish to remove lice and reduce parasite loading. The essay would balance the need for genetic modification to improve yield and growth performance while acknowledging the risks associated with such fish escaping into the wild. On-shore cultivation would be a mitigation for the latter. On-shore cultivation has many advantages but has high energy costs, although these could be mitigated through the use of renewable energy in the future.

Novel developments such as automated offshore deepwater fish cages, the use of integrated multitrophic systems (using plants, algae and urchins) to remove wastes and generate secondary products would be included.

14.2 Is fish farming cruel?

A good question would give a balanced view presenting evidence from the physiological studies focussed on the concept of pain reception in fish. Key to this issue is the idea that fish lack critical areas of brain function that might lead to the conclusion that they cannot feel pain in the same way as a higher vertebrate. A balanced essay would consider potential benefits that are argued by recreational anglers (sport fishers) in terms of habitat enhancement and food supplements. An ethical and philosophical view point would be presented, and the difficulty in dealing with an issue that inevitably leads to anthropomorphisms should be acknowledged.

The essay would draw on studies that have looked at behavioral and physiological responses of fish in aquaculture settings and would consider how the industry has responded to the science to improve conditions. A consideration of the species traits that would make them unsuitable for cultivation (or would present problems) is highly relevant, e.g. aggressive/territorial species such as salmon can exhibit high levels of aggression when maintained in high density. Other species are less stressed when kept in high density due to the ‘herd’ effect and lower risk of predation when living in groups. The essay would also consider what measures have been taken to improve the husbandry conditions of fish in cultivation systems from the hatchery through to the point of slaughter. The commercial advantages of improved welfare should be discussed as a win-win situation.

Intensive cultivation can also lead to environment problems in the immediate environs of the cultivation system. These environmental problems can lead to increased stress for the fish through depletion of oxygen in the water column. Consideration of the management mitigation practices would include rotating cages from one area of a water body to another. The use of biological controls on infestations of lice (e.g. using wrasse) should also be considered, including the welfare issues for the cleaner fish.

Ultimately the essay should arrive at a conclusion either one way or the other, but this should be evidenced throughout. There is no ‘right’ or ‘wrong’ answer to this question, what your marker will look for is a coherent, balanced and well argued essay.

Chapter 15

15.1 Excluding the effects of climate change and fisheries, discuss the various impacts that human interventions in natural systems can have on the marine environment.

Do not fall into the trap of talking about the effects of climate (and ocean acidification which is linked to climate) as this is specifically not requested. Basically this essay requires a consideration of a list of impacts that might include; aggregate extraction, mining, deep sea mining, drilling for hydrocarbons, transport of oil, land reclamation, damming of rivers and hence impacts on discharges, inputs of pollutants, dumping of contaminants such as sewage. This list is not exhaustive. Before diving into dealing with this list, the essay would sensibly start with a consideration of more general issues such as scale and relative risk and potential for recovery. For each of the listed impacts it would be necessary to highlight the main effects, where they occur, what they have an effect upon, the timescale over which recovery occurs and the actions that can be taken to avoid them. A good essay would draw out similarities and differences among the different types of effects using perhaps a conceptual diagram to show how these impacts might group (e.g. according to scale, intensity etc). Some reference to natural disturbance events to add context to the answer would be sensible, hence cross-reference this answer with the considerations in the answer to Chapter 8.

Chapter 16

16.1 Why do people want to conserve the marine environment and what are the factors affecting the success of conservation policy?

Justifications for conservation range from those that are moral and ethical to those that focus on the maintenance of the services provided by ecosystems. Different societies and different users with different needs and different values have different perspectives on the need for conservation.

A good essay would summarise some of the main justifications for conservation such as moral and ethical considerations and the benefits of a sustainable food and income supply, but would also recognise that these benefits are perceived in different ways by different users and societies. The essay may develop contrasts between the wealthy and poorer regions of the world in terms of their reliance on the marine environment and capacity to take conservation action. It would be helpful to frame some of these discussions against international commitments such as the U.N. Sustainable Development Goals and the Convention for Biological Diversity (CBD). A good essay would draw on examples that relate to different sectors and different countries, with examples taken from the literature. It may also look at the strengths and weaknesses of the different tools that are used to implement conservation policy, such as marine reserves.

Chapter 17

17.1 Describe how climate change is affecting coastal communities (human) and biological processes in marine systems.

This question falls into two parts, but they are linked, and a good answer would demonstrate these links. Firstly, perhaps deal with the biological processes. Consider the main impacts, warming temperatures, rising sea level (hence changes to coast currents and circulation patterns), acidification of the ocean. At the outset, frame the context and the amount of increase in temperature that has occurred, but also point out that the physical changes (temperature and rainfall) change differently in different parts of the world. From a biological perspective, think about phenology (timing of egg hatching, larval development and coincidence with suitable prey species), metabolism (leading to organisms with smaller bodies sizes due to physiological responses to warmer seas), changes in species distribution (e.g. warm water species infiltrating temperate systems and cold water species shrinking in terms of distribution. Consider also the changes in physical processes, such as tidal circulation (larval distribution patterns), storminess and its effects on stratification, increased river discharge and elevated eutrophication in coastal regions, changes to ice cover and the associated implications (outlined in the answer for Chapter 12).

For coastal communities, seawater inundation is a major threat in low lying countries and coastal erosion is likely to increase due to increased storm intensity in certain parts of the world. Anoxic events will lead to local fishery collapses. Changes in species composition will create challenges for fishers due to the need to change fishing practices to catch (or avoid catching) novel species. Some of these changes might also be seen as opportunities (e.g. the ability to catch certain fish all year compared with more seasonally in the past).

The answer should be well illustrated with detailed examples in specific locations, ideally contrasted with opposite effects if they exist (e.g. increasing rainfall in the temperate north, decreasing rainfall in regions of Africa).

Chapter 18

18.1 Which economic factors influence human use of the marine environment and how can economic analysis be used to inform conservation decision making?

The environmental costs of use of the marine environment are rarely paid for by the businesses, governments, and individuals that profit from this use. Not accounting for the environmental cost of human activities means that development is often driven by false economic incentives and disincentives, and is unlikely to be sustainable. Economic analyses can be used to inform decisions about conservation because they allow the overall effects of different management options or scenarios to be explored in a systematic way.

A good essay would explain that the environmental costs of using the marine environment are rarely paid for by the user and give examples of activities that benefit users but not the environment, ideally presenting some examples from the literature in addition to those in the book. Examples here would include: fisheries, marine shipping, recreational uses such as diving and kayaking. Exceptions would include renewable energy and aquaculture companies that are required to pay for licenses for permission to utilise a specific space in the sea. The essay would describe what ecosystem services are and that they can be valued. A good essay would provide some examples to highlight differences in total economic value associated with different uses of the environment and highlight the conservation consequences of these valuations.

Extending these ideas further, you might focus on how layering in the economic and social uses of the sea adds a further dimension to considerations about marine spatial planning or the siting of marine protected areas. Use examples to illustrate marine spatial planning e.g. in Holland or another example such as the Great Barrier Reef (Chapter 16). Additionally, it would be good to illustrate how economic and social sciences can be used to adjust or optimise marine protected area design to maintain conservation goals but reduce economic and social costs.