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Lecture Notes

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DISEASES IN OCEAN ECOSYSTEMS AND THEIR DYNAMICS IN RELATION TO CLIMATE CHANGE

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Introduction

Existing and emerging pathogens pose unusual challenges to marine life, because of their potential to drive rapid changes in the numerical abundance and composition of host populations. Disease outbreaks, due to parasites (protozoans, crustaceans and helminthes) and microbial pathogens (bacteria, fungi and virus) alter the structure and function of marine ecosystems, directly affecting vertebrates and invertebrates. Although the important pathogens in terrestrial ecosystems have long been recognized and studied, the role of diseases in most marine communities is comparatively unknown and such studies are limited. Quantitative analysis of the scientific literature of the past four decades indicates a large increase in the number of reports about marine diseases in molluscs, corals, marine mammals, turtles and echinoderms (Kim *et al*. 2005; Table1). In this context, it would be of great importance to analyse the basis and timing of marine disease events and pathogen profile in relation to the major environmental events such as climate change. The ecological and biological impacts of diseases in the oceans remain largely unknown in spite of the negative impacts of diseases to the marine ecosystem.

Factors responsible for disease outbreak in the oceans

Two ways in which climate change and human activity can increase the emergence of new diseases are by increasing the rate of contact between novel pathogens and the host populations, and by altering the environment in favour of the pathogen. Climate change and human activity have altered or degraded the marine habitats and marine life, increasing stress mediated susceptibility to diseases.

Human Activity and Climate Change

Increased human activity and climate change act as a catalyst for the emergence of new diseases, affecting increasing number of species. Climate warming can increase pathogen development and survival rates, disease transmission and host susceptibility. Human activity along the coastal regions for domestic and industrial purposes leading to polluted environments could be a major factor in the emergence of disease-causing pathogens and disease dynamics. The human activities such as ocean aquaculture, release of ballast water from shipping vessels and release of poorly treated sewage are showing a steady increase, affecting health of the ocean ecosystem. Eutrophication due to runoff of nutrients and organic materials may also cause an increase in the abundance of diseased organisms. Further, a variety of chemical contaminants, especially polychlorinated biphenyls (PCBs), DDTs and organometals can bioaccumulate up the food chain and are detected in tissues of marine animals (O'Shea, 1999). The effect of these contaminants can cause dysfunction in the physiological and immune functions of the animals, making them susceptible to disease causing pathogens. It could be noted that majority of the new diseases are not caused by new micro-organisms, but mostly by known microparasites and macroparasites, infecting new or previously unrecognized hosts. A number of fecal bacterial isolates from coastal marine mammals revealed multiple antibiotic resistance (Johnson *et al*. 1998) probably resulting from exposure to bacteria of human origin, as these animals have not been previously treated with antibiotics.

Novel host-pathogen interaction

Increased contact between marine mammals and humans or domestic animals appears to have enhanced transmission of diseases to marine mammals. An example of the introduction of a new pathogen into sea environment by human activity is the introduction of the canine distemper virus (CDV) into seals in Antarctica by contacts with infected sledge dogs used during an Antarctic expedition (Bengston *et al*.

1991). Later, a virus closely resembling the CDV, the dolphin morbillivirus (DMV) was shown to be the case of mass mortalities and disease outbreaks among dolphins all over the world (Domingo *et al*. 1990). Other examples include detection of human influenza virus in seals, where more than 400 mostly immature harbour seals died of acute pneumonia associated with influenza virus along the New England coast between December 1979 and October 1980 (Geraci *et al*. 1982).

Climate Change induced diseases

In the marine realm, water temperatures appear to play an important role in disease dynamics. The El Nino Southern Oscillation (ENSO) is one of the visible climate variations that has had large-scale effects on marine ecosystems. ENSO events are linked to outbreaks of 'Dermo' disease of the eastern oyster (*Crasostrea virginica*) caused by the protozoan parasite *Perkinsus marinus* (Kim and Powell, 1998). In the Gulf of Mexico, the apparent relationship between Dermo and ENSO reveals that the infection intensity and prevalence of Dermo drop during the cool and wet El Nino events and rise during warm and dry La Nina events (Powell *et al*. 1996). Cold water disease of salmonids is favoured by low temperature regimes, where infection appears when water temperatures are at 4 - 10æ%C, and disappear in warmer water (Holt *et al*. 1989). As humans disturb natural balances, break transmission barriers among species and reduce host population sizes, outbreaks of new or generalist pathogens among rare or threatened host species might become more common.

Also, the impact of the climatological changes on marine species is clearly evident among corals, which are known to bleach (resulting in the coral mortality) in response to a range of environmental stresses (Ward *et al*. 2006). Elevated sea surface temperature due to El Nino events is a common explanation for coral bleaching. In 1999, gorgonian corals, zoanthids and sponges in the Mediterranean Sea were affected by a temperature-linked epizootic, where mortality resulted from the effects of environmental stress and unidentified opportunistic pathogens (Cerrano *et al* 2000). The mortality recorded among the gorgonian corals was 60-100%. Growth rates of marine bacteria and fungi are positively correlated with temperature (Shiah *et al*. 1994; Holmquist *et al*. 1983). Leptospirosis is a bacterial disease among the Californian sea lions that recurs at approximately four-year intervals, generally after El Nino years (Gulland *et al*. 1996). ENSO events are expected to become commonplace within 20 years, with possibilities of large scale loss of coral reefs, on a global scale.

Control of diseases in oceans

Control of diseases in wild terrestrial populations involves classic techniques such as vaccination, culling, quarantine, the HACCP (hazard analysis and critical control points), and development of resistant transgenics. However, these traditional techniques are unlikely to be effective in open marine environments. In this situation what we need is to evolve a long term strategy for ocean environment, by bringing the proven models from terrestrial system and applying these in the ocean environment. The absence of long term data on disease dynamics in the oceans limits our understanding of the role and importance of diseases in the sea. Hence we need to have region-specific scientific monitoring programmes to track the disease dynamics in marine life in relation to the changing environmental regimes. Pathogen identity, transmissibility, dispersal mechanisms, host specificity, factors affecting disease virulence, host susceptibility to disease causing pathogens, and other basic features of the diseases are important for devising a meaningful disease control mechanisms.

Epidemiological models and disease forecasting

Epidemiological models developed for the study of humans and other land based animal diseases have not been successfully applied to marine life management. Adapting such models to marine organisms requires deeper understanding about the disease dynamics in relation to the environmental factors, which is rather a complex phenomenon in the oceans. Application of modern DNA-based diagnostics would be useful in the early detection of disease outbreaks, as well as determining the host specificity, and even the origin of the pathogen. A multidisciplinary approach involving different disciplines of health management such as microbiologists, pathologists, molecular biologists, epidemiologists, ecologists and environmentalists is critical to a fuller understanding of marine pathogens and disease problems in ocean life. A holistic approach involving all the above factors may deliver enough data to improve our ability to develop disease forecasting models in oceans with environmental or climate sensitivity. With greater understanding of the interaction between environments, marine organisms along with the pathogens, we would be able to make predictions about the effects of changing climate and environment on disease out breaks in marine ecosystems.

Glossary

Disease: a condition of a plant or animal that impairs normal function. A disease has a defined set of signs and symptoms, but is not necessarily caused by a transmissible biological agent. Commonly, however, 'disease' is used as shorthand for 'infectious disease'. I have uses this shorthand in this paper where it does not lead to ambiguity.

Epidemic: an outbreak of a parasite (usually a microorganism) in a population that increases rapidly, reaches a peak and then declines. The etymology (Greek demos: people) leads some authors to restrict the term to pathogen outbreaks in humans, with epizootic used for pathogens of non-human animals and epiphytotic used for pathogens of plants. We use the term to refer to outbreaks in either animals or plants.

Macroparasite: Usually (but not invariably) multicellular metazoans such as helminths that cannot complete an entire life cycle within one individual host.

Microparasite: Unicellular microorganisms, such as viruses, bacteria and protozoans that can multiply rapidly within a host.

Open: an open population or community is one in which most recruitment comes from external sources.

Parasite: an organism that lives in an intimate and durable association with one host individual of another species per life history stage. It has a detrimental effect on the host. Pathogens, parasitoids and parasitic castrators are subsets of parasites.

Vector: a mobile organism that transmits a parasite from one host to another.

Virulence: the degree of harm caused by a parasite to an infected host. Sometimes, this concept is confused with transmissibility, which is how easily the parasite spreads between hosts.

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Table 1. Mass mortality incidents among natural populations of selected marine organisms

Start Date	Host species	Out break Location	Pathogen Identity	Estimated Mortality (%)
1946	*Crassostrea* (oyster)	Gulf Coast, U.S.A	*Perkinsus marinus*	Extensive
1954	*Clupea* (herring)	Gulf St. Lawrence	*Ichthyophonus hoferi*	50
1955	*Lobodon* (seal)	Antarctica	Virus	Extensive
1974	*Ostrea* (flat oyster)	Northwestern Spain	*Marteilia refringens*	Extensive
1975	*Heliaster* (starfish)	Western U.S.A	?	<100
1980	*Strongylocentrotus* (urchin)	Northwestern Atlantic	Amoeba?	>50
1980	*Ostrea* (oyster)	Netherlands	*Bonamia ostreae*	Extensive
1981	*Acropora* (coral)	Caribbean wide	Bacteria?	>100
1982	*Gorgonia* (coral)	Central America	?	Extensive
1982-86	*Haliotis* (abalone)	Australia	*Perkinsus* sp.	Extensive
1983	Corals	Caribbeanwide	Microbial consortium	
1983	*Patinopecten* (scallop)	Western Canada	*Perkinsus qugwadi*	Extensive
1983	*Diadema* (urchin)	Caribbeanwide	Bacteria ?	>95
1985	*Haliotis* (abalone	Northeastern Pacific	?	>95
1986-90	*Ruditapes* (clam)	Portugal	*Perkinsus atlanticus*	Extensive
1987	*Thalassia* (seagrass)	Florida, U.S.A.	Slime mold	>95
1988	*Argopecten* (scallop)	North Caribbean	Protozoan	Extensive
1988	*Phoca* (seals)	Northwestern Europe	Virus	70
1989	*Argopecten* (scallop)	Eastern Canada	*Perkinsus* sp.?	Extensive
1989	*Phoca* (seals)	Lake Baikal	Virus	>10
1990	*Stenella* (dolphin)	Western Mediterranean	Virus	>20
1991	*Clupea* (herring)	Western Sweden	*Ichthyophonus hoferi*	>10
1992	*Ecklonia* (kelp)	Northeastern new Zealand	?	40-100
1993	*Coralline algae*	South pacific	Bacteia ?	Extensive
1995	*Strongylocentrotus* (urchin)	Norway	Nematode ?	90
1995	*Gorgonia* (corals)	Caribbeanwide	Fungus	Extensive
1995	*Dichocoenia and others* (coral)	Florida, U.S.A	Bacteria	<38
1996	*Diploria and others* (coral)	Puerto Rico	Bacteria	Extensive
1997	*Porolithon* (algae)	Samoa	Fungus	Extensive
1997	*Sardinops* (pilchard)	Southern Australia	Virus?	Extensive
1997	*Monachus* (seal)	West Africa	Virus/toxin	>75
1999	*Gorgonian corals*	NW Mediterranean	Protozoan/fungi?	>20
2000	*Phoca* (seal)	Capsian Sea	Virus	Extensive
2002	*Phoca* (seal)	N Europe	Virus	>10
2003	Krill	NW US	*Collinia* sp (ciliate)	?