Qatar Univ. Sci J. (1999), 19:

PARASITES AS INDICATORS OF ENVIRONMENTAL CHANGE AND POLLUTION IN MARINE ECOSYSTEMS

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Key words : *Environmental change, Marine ecosystems, parasites, Pollution.*

ABSTRACT

Good biological indicators to monitor the effects of pollutants on marine organisms must be exceptionally sensitive to environmental change so that a significant reduction in their numbers can be used as a warning of deteriorating conditions before the majority of less sensitive organisms are seriously affected. There are good reasons for focusing on parasites in the search for such indicators. Firstly, there are more parasitic than free-living species and parasitic organisms show enormous biological diversity, reflecting adaptations to the parasitic way of life in different types of host and in diverse sites and environments. Secondly, in metazoan parasites with complex life cycles, the different developmental stages have widely differing biological requirements, so that each stage must be assessed separately, thereby greatly extending the number of potential indicators. Thirdly, many parasites have delicate short-lived free-living transmission stages which are highly sensitive to environmental change. They can therefore be adversely affected by even minor changes in the environment. A reduction in their transmission rate, and consequently in their levels of infection, will serve as an early warning that changes are occurring. Conversely, many ectoparasites are highly resistant to environmental change and will respond to such change by increased levels of infection. As a general rule, infections with endoparasitic helminths with complex indirect life cycles tend to decrease, while infections with ectoparasites with direct single-host life cycles tend to increase, with increasing levels of pollution. However, there are enormous variations in the responses of different parasite taxa to different pollutants.

INTRODUCTION

Good biological indicators to monitor the effects of pollutants on marine organisms must be exceptionally sensitive to environmental change so that a significant reduction in their numbers can be used as a warning of deteriorating conditions before the majority of less sensitive organisms are seriously affected. The use of parasites as indicators of aquatic pollution has been reviewed by Möller (1), Khan and Thulin (2), MacKenzie *etal.* (3), Lafferty (4) and Overstreet (5).

There are good reasons for focusing on parasites in the search for such indicators.

1- There are more parasitic than free-living species on earth (6) and parasitic organisms show enormous biological diversity reflecting adaptations to the parasitic way of life in different types of host and in diverse sites and environments.

2- Add to this the fact that in metazoan parasites with complex life cycles, the different developmental stages have widely differing biological requirements, so that each stage must be assessed separately, thereby greatly increasing the number of potential indicators.

3- Many parasites have delicate short-lived free-living transmission stages which are highly sensitive to environmental change. They can therefore be adversely affected by even minor changes in the environment and so represent weak links in the life cycles of the parasites.

While many parasites are extremely sensitive to environmental change, others are more resistant than their hosts and tend to increase in numbers in polluted conditions. As a general rule, infections with endoparasitic helminths with complex indirect life cycles tend to decrease, while infections with ectoparasites with direct single-host life cycles tend to increase, with increasing levels of pollution. However, as Lafferty (4) has shown, there are enormous variations in the responses of different parasite taxa to different types of pollution. The numbers of trichodinid gill ciliates of fish, which have direct single-host life cycles, increase with several types of pollution (Table 1). In contrast, the numbers of digeneans, cestodes and acanthocephalans, which have complex indirect life cycles, have been found to decrease with most types of pollution.

(Table 1)

Effects of different types of pollution on different parasite taxa. Plus signs indicate an increase in parasite abundance, minus signs a decrease, and blank spaces indicate where no data are available. (After Lafferty [4]).

Type of pollution	Parasite taxa					
	Ciliophora	Monogenea	Nematoda	Digenea	Cestoda	Acanthocephala
Eutrophication		+	+	+	+	+
Thermal effluent	+		+	-		
Pulp-mill effluent	+	-	-	-		
Crude oil	+	+	+	-		-
Industrial effluent	+		-	-	-	-
Sewage sludge					+	-
Acid precipitation		-		-	-	+
Heavy metals				-	-	-

II- A PROPOSED EARLY WARNING SYSTEM

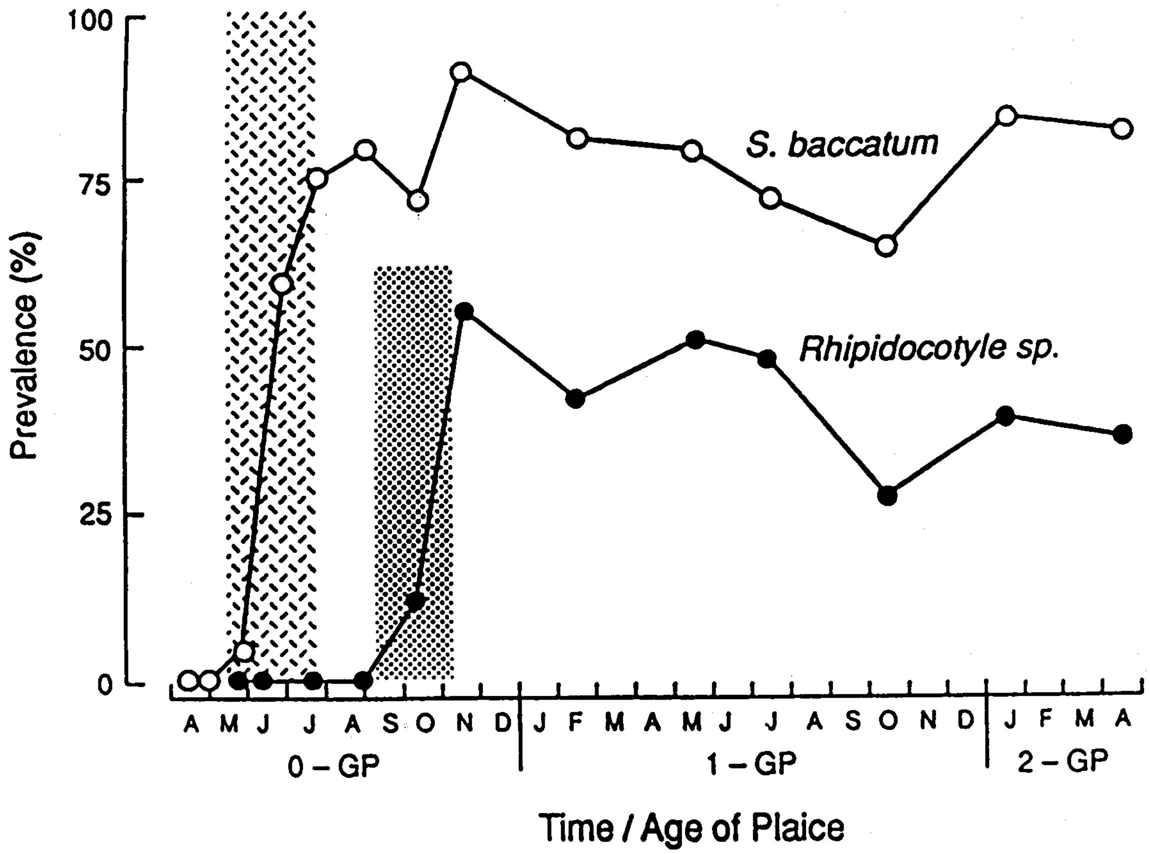
Until recently, attempts to use parasites as indicators of marine pollution focused on the pathology associated with parasitic infections. This approach, however, is limited by lack of sensitivity and delayed response, as pointed out by McVicar (7). Most obvious pathological conditions are the end result of a sequence of events that may have occurred over a prolonged period and therefore relate to changes in environmental conditions dating back some considerable time. This is particularly true of pathology resulting from infections with metazoan parasites, which have longer generation times than micro-organisms such as viruses, bacteria and protozoans, and consequently take longer to build up their populations to levels likely to cause disease. Some of the free-living transmission stages of metazoan parasites, particularly the helminths are delicate short-lived larvae that are highly sensitive to changes in environmental conditions. Monitoring the transmission of selected metazoan parasites is therefore likely to provide a much more rapid response to environmental change.

1- Transmission Routes and

Transmission Windows.

A *transmission* route is the pathway through which a parasite progresses from one developmental stage to the next and from one host to another. Most parasites have a range of possible host species resulting in a number of possible transmission routs.The number of routes is greatly increased in parasites with life cycles involving three or more hosts at different stages of development. For example, a digenetic trematode will usually infect only one species, or a small group of closely related species, of primary host, usually a mollusc, but may have a wide range of intermediate or definitive host species. These intermediate hosts can be arranged along a continuum form those to which the parasite is best adapted and which provide it with the highest probability of successful transmission to the next stage, to «dead-end» hosts or «ecological sinks» through which no further development is possible (8).

Associated with each transmission route is a *transmission window*. This is the period during which transmission of the parasite from one host to anther can take place. The length of this period depends on the concurrence of infective stages of the parasite with hosts that are susceptible to infective stages of the parasite with hosts that are susceptible to infection. With some transmission routes the windows are open throughout the entire life span of the host so infection can take place at any time. In others the windows are brief seasonal periods which represent weak links in parasite life cycles where routes through certain host species may be easily disrupted by changes in environmental conditions. Examples of two such narrow transmission widows are illustrated in Fig. 1. MacKenzie and Gibson (9) showed that infection of plaice *Pleuronectes platessa* with metacercariae of the digeneans *Stephanostomum baccatum* and *Rhipidocotyle* sp. occurs only in the first year of life, for *S. baccatum* during June and July and for *Rhipidocotyle* sp. form about the middle of September to the end of October. Transmission of each of these parasites to plaice is therefore limited to a period of 6-8 weeks in a host species with a maximum life span of over 20 years. This limited period is determined by two things ; plaice are susceptible to penetration by the cercatiae only when they are very young, and there is only a short annual period when free-swimming cercariae emerge from the mollusc host. In a year when emergence or viability of cercariae or growth of plaice is disrupted by a change in environmental conditions, an entire year class of plaice might show a significantly reduced level of infection.



(Fig. 1)

Another good example of a narrow transmission window is infection of herring *Clupea harngus* with the digeneans *Cercaria doricha* and *C. pythionike.* Free-swimming cercariae emerge form the mollusc host during a period of about three months in spring and early summer and herring become infected by ingesting the brightly-coloured cercariae which penetrate the gut wall and encyst in the visceral cavity (10). All infection of herring takes place in the first summer of life, when they are feeding on planktonic organisms of about the same size as the cercariae. The fastest growing juvenile herring apparently progress to feeding on larger organisms before the end of the period of cercarial emergence (11).

Transmission is therefore limited to a period of one to three months in a host species with a maximum life span of over 20 years, In a year when conditions favour the rapid growth of juvenile herring and/or cercarial emergence is delayed or inhibited, levels of infection could be greatly reduced.

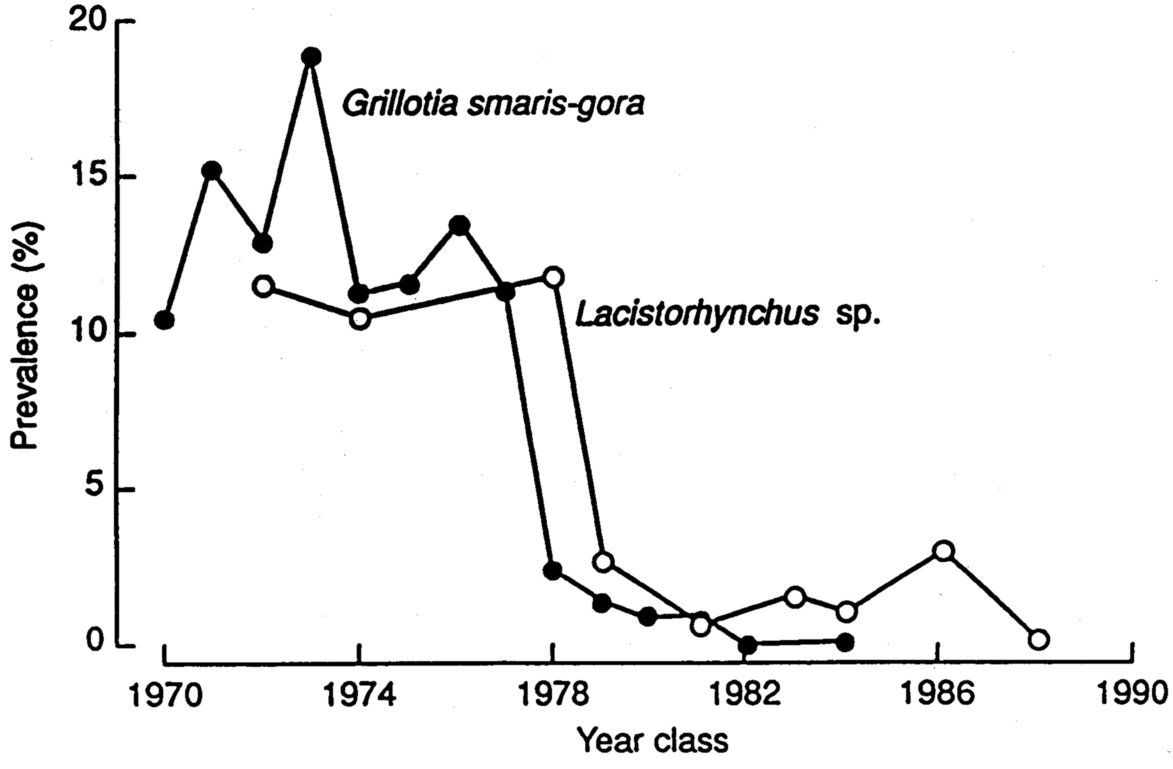
A freshwater example of a narrow transmission window was described by Kennedy (12), who showed how annual variations in the timing of cercarial emergence and fish host spawning determined the levels of infection by a digenean in different year classes of perch *Perca fluviatilis.*

The above examples all feature digeneans, but other helminths also have narrow and vulnerable transmission windows in their life cycle. A good example of how human interference with an ecosystem can drastically affect the transmission of a cestode parasite is given by Hanzelova (13). In the year following drainage of a freshwater reservoir in the Czech Republic, the species composition of the copepod community and the seasonal dynamics of copepod numbers changed dramatically. The copepod serve as intermediate hosts for the fish cestode *Proteocephalus neglectus* and the effect on transmission of this parasite was that infection of rainbow trout *Oncorhynchus mykiss* in the reservoir decreased by 97.5% from one year to the next.

2. Reported Transmission Failures of Marine Parasites

Nagasawa *etal.* (14) described how transmission of the parasitic copepod *Pennella* sp. to its fish host, the saury *Cololabis saira*, in the western North Pacific failed in 1985. No infected saury were found in this region in 1986, but the parasite's reappearance in 1990 was reported by Honma and Imai (15).

Transmission of *Pennella* sp. is direct from fish to fish without the intervention of an intermediate host, but Fig. 2 shows examples of sudden transmission failures of two marine cestode parasites with complex three-host life cycles. MacKenzie (16) described transmission failures of the cestode *Grilloteia smaris-gora* and *Lacistorhynchus tenuis* to their fish hosts mackerel *Scomber scombrus* and herring *C. harengus* respectively in European waters. Infection of herring begins in the first, and of mackerel in the second year of life. In year classes of both host species form 1970-1972 to 1978 prevalences of both cestoedes remained fairly stable, but in 1979 prevalences of both species were dramatically reduced and had not recovered when sampling stopped in 1984 for mackerel and in 1988 for herring. The reasons for both the above examples of transmission failures are unknown, but they are probably related to natural environmental changes. It may be significant that the sudden change in prevalence of the two cestodes coincided with the end of a hydrographic phenomemon in the North Atlantic knows as the mid-70s salinity anomaly, but if the events were indeed linked, it is likely to have been through a complex series of causes and effects involving changes in a number of biotic and abiotic factors. In the above examples, plaice herring and mackerel are not important host species for maintaining the populations of these particular parasites. Because they are likely to be particularly vulnerable to



(Fig. 2)

changes in environmental conditions, narrow transmission windows associated with less important hosts in the life cycle of a parasite could provide a highly sensitive early warning of marine pollution. The non-appearance of a parasite in one of its less important host species does not necessarily mean that the parasite has disappeared form the area. It may still maintain its population by continuing to infect its more important host species. From the point of view of using the parasite as an indicator the important point is that a vulnerable link in the monitored transmission route has been broken and a warning bell has sounded.

3. Selection of Suitable

Host-parasite Systems

In selecting host-parasite systems to monitor as early warning indicators of marine pollution, the aim is to identify those that are so delicately balanced that certain environmental changes will lead to transmission failures.

The subject host should be a species which is common and resident in the study area so that regular samples can be taken without significantly affecting the population and one can be sure of sampling the same host population on each occasion. Although the above examples have focused on fish as hosts, invertebrates, particularly benthic species of crustaceans and molluscs, may be better choices in some situations. Juvenile fish which use the study area as a nursery and are resident in the area for a known period of time should also be considered. Most adult fish, particularly pelagic species, are migratory to some extent and should not be selected unless the study area is known to cover their full migratory range.

The following criteria are suggested for the selection of an indicator parasite species.

1 - It should occur commonly in the subject host.

2 - It should be readily identifiable and not easily confused with similar species infecting the subject host. Related or sibling species which are morphologically very similar may have quite different environmental sensitivities.

3 - Its ecology and life cycle should be reasonably well known form previous studies.

4 - It should have a narrow transmission window for infection of the subject host.

5 - If the suspected pollutants accumulate in sediments, as many tend to do, the parasite should have transmission stages, such as eggs or free-living larvae, which are in contact with the sea bed. This, of course, does not apply to water-soluble chemicals or abiotic pollutants such as thermal changes.

6 - It should be borne in mind that parasite species living near the limits of their geographical distributions are likely to be particularly vulnerable to environmental change.

7 - Free-living transmission stages of the selected parasite should be exposed to the pollutants being investigated under controlled laboratory conditions and their subsequent viability and infectivity for the subject host tested.

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