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PARASITES AS BIOLOGICAL TAGS IN POPULATION STUDIES OF MARINE ORGANISMS

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ABSTRACT

Parasites have been used to identify and trace the migrations of different intraspecific populations of commercially important marine fish since 1939, Literature research shows how the numbers of publications involving this method of tagging has increased in every successive decade since then, reflecting increasing interest. More recently the same approach has been applied to population studies of marine invertebrates, such as squid and prawns and of marine mammals. The efficiency of the method improves as research adds to our knowledge of the biology of marine parasites, particularly their life cycles. This paper describes the general principles of using parasites as biological tags and highlights the advantages and disadvantages of the method. It offers guidelines to the selection of the most appropriate tags for the main tubes of population study ; stock discrimination, recruitment studies and seasonal migrations. It also gives a guide to the interpretation of results following analyses of the parasitological data. These results are often open to more than one interpretation; the correct one is arrived at by a process of elimination.

Tow main approaches to the use of parasites as tags are recognised. In one, a small number of parasite species are selected according to established criteria and a large number of host individuals are examined specifically for these species. In the other, entire parasite assemblages are analysed using sophisticated statistical methods. Examples are given of each approach and of the use of parasite tags for each type of fish population study, together with examples of the use of parasites as tags in population studies of marine invertebrates and cetaceans.

INTRODUCTION

Naturally occurring parasites can be used as indicators of various aspects of the biology of their hosts. This paper deals with their use as biological tags in population studies of marine fish, invertebrates (crustaceans and squid) and cetaceans. The earliest study of this kinds is that of Herrington *et al.* [1], who suggested the existence of separate populations of redfish *sebastes* spp in the Northwest Atlantic on the basis of geographical variations in levels of infection of a parasitic copepod. The increasing frequency of publications referring to the actual or potential use of parasites as tags in population studies of aquatic organisms reflects increasing recognition of the value of parasites in this context (Table 1).

These publications include the reviews of Sindermann [2,3], Kabata [4], MacKenzie [5,6], Lester [7], Moser (8). Williams *etal.* [9] and MacKenzie and Abaunza [10]. The basic principle underlying the use of parasites as tags in host population studies is that hosts can become infected with a particular parasite species only when they are in the endemic area of that parasite. The endemic area is the geographical region in which environmental conditions are suitable for reproduction of the parasite and where all the hosts essential for completion of its life cycle are present. If infected hosts are found outside this area, one can infer that these hosts had been within the endemic area at some time in their past history. Information on the life span of the parasite in that particular host will allow the researcher to estimate the maximum time since infection and therefore since the hosts left the endemic area. The more parasites with different endemic areas that can be used, the more information that can be obtained about the past movements of host populations.

The use of parasites as biological tags gas been shown to have certain advantages over the use of artificial tags.

1. They are more appropriate for studies of deepwater fish and small delicate species which are unlikely to survive capture and handling. They are also more appropriate for crustaceans which tends to shed artificial tags when they moult.
2. They are less expensive because samples can be obtained form routine sampling programmes or from commercial catches.
3. They eliminate doubts concerning possible abnormal behaviour of artificially tagged hosts.

on the other hand, the following limitations to the use of parasites as tags were pointed our by Sindermann [3].

1. Lack of information on the ecology and biology of aquatic parasites limits their use as tags. However, parasite tagging is becoming more efficient as research in these areas adds to our knowledge.
2. The identification of many parasite species is uncertain and subject to disagreement among taxonomists. The recent application of molecular biology techniques to parasite taxonomy has resulted in the identification of "sibling" species in parasites which had previously been

regarded as comprising a single species [11]. Conversely, the same techniques have shown that parasites which had previously been regarded as separate species may in fact be conspecific [12]. It should also be pointed out that although these findings may appear to complicate the use of certain parasites as tags, the additional knowledge may also lead to greater accuracy.

3. It is usually desirable to know the age of host individuals, but in some species the techniques of age determination have not been validated.

II- METHODOLOGY

1 - General Approach

There are tow main approaches to the use of parasites as biological tags.

1. A small number of parasite species are selected according to the criteria outlined below and a large number of fish are examined for these parasites only. This approach is most applicable to studies of host species which are readily available for examination in large numbers and usually requires only simple univariate statistical analyses.

2. Entire parasite assemblages are analysed using more complex and sophisticated multivariate statistical techniques. This approach can be applied to any host species but is particularly applicable to those which are large and valuable and are not readily available for examination in large numbers, Good examples are the studies of Speare [13, 14]. who analysed the entire metazoan parasite fauna collected from samples of two species of large game fish, the black marlin *Makaira indica,* and the sailfish *Istiophorus platypterus* in eastern Australian waters. Only 63 marlin and 52 sailfish were available for examination, yielding 31 and 36 parasite taxa respectively, which Speare divided into two groups, permanent and semi-permanent, according to their probable life spans in the fish. Ordination and classification analyses of the parasite taxa provided valuable information on the migrations of both host species in the study area.

2 - Selection Criteria (Applicable to method 1 above)

Initially, the entire protozoan and metazoan parasite fauna of the subject host species should be noted, using literature records and pilot studies carried out in the study area. The most promising tag prasites can then be selected according to their possession of the following features.

1. Significantly different levels of infection in different parts of the study area.
2. A long life span in the subject host.
3. A stable level of infection with time (The effects of annual variations in levels of infection can be compensated for by following infections in single host year classes over several years).
4. Ease of detection and identification, otherwise examination time can become a limiting factor.
5. No serious pathogenicity, Parasites that kill, severely debilitate or change the behaviour of the subject host should not be considered.

(Table 1)

Types of host population study for which parasites have been used as biological tags, with examples and references.

Type of study	Host sp.	Parasite sp.	Location	Reference
Stock separation				
Marine fish	*Makaira indica*	Entire assemblage	Eastern	13
	Istiophorus platypterus	Entire assemblage	Australia	14
	Merlangius merlangus	Myxosporea: *Ceratomyxa arcuata*, *Myxidium sphaericum*	North Sea	16
Marine mammals	*Globicephala melas*	Digenea: *Hadwenius subtilis*, *Hadwenius delyamurei*; Cestoda: *Trigonocotyle globicephalae*; Acanthocephala: *Bolbosoma capitatum*	Faroe Islands	17
	Physeter catodon	Acanthocephala: *Corynosoma* spp.	Antarctic and Sub-Antarctic	18
Marine invertebrates	*Pandalus jordani*, *Pandalopsis dispar*	Digenea: *Neolebouria tinkerbellae*, 'Metacercaria A'	British Columbia, Canada	20

(Cont. Table 1)

Recruitment studies				
Anadromous fish	*Oncorhynchus nerka*	Cestoda: *Triaenophorus crassus* Nematoda: *Truttaedacnitis truttae*	North Pacific Ocean	21
	O. nerka	Myxosporea: *Henneguya salmincola* *Myxobolus arcticus*	British Columbia Canada	22
Marine fish	*Clupea harengus*	Digenea: *Cercaria doricha* *Cercaria pythionike* Cestoda: *Lacistorhynchus tenuis*	Northeast Atlantic	24
Marine invertebrates	*Penaeus merguensis*	Cestoda: *Polypocephalus* sp. Isopoda: *Epipenaeon ingens*	Northern Australia	26, 27
Seasonal migrations				
Marine fish	*Clupea harengus* *Belone belone*	Cestoda: *Lacistorhynchus tenuis* Nematoda: *Anisakis simplex*	Baltic Sea	27, 28

3 - Interpretation of Results

When all the data have been analysed, the results may be open to more than one interpretation in terms of host population movements. All possibilities must be considered in the light of the available information on the biology of both host and parasite until all but one has been eliminated. As more information on the biology of marine parasites becomes available, the interpretation of these data becomes more accurate.

III- TYPES OF POPULATION STUDY

These types are listed in Table 2. The selected examples are described in detail below.

1 - Stock Separation

This type of study aims to identify different intraspecific groups or stocks which differ in certain key aspects of their biology, usually in having different geographical distributions or migratory patterns.

1.1 - Marine fish

The classic studies of Kabata [4,16], using myxosporean parasites, are amongst the best examples of this type. Four genera of these parasites, each with easily identifiable spore morphology, infect the gall bladders of gadoid fish, including whiting *Meralngius merlangus,* in the Northeast Atlantic. Kabata used two of these genera to identify two stock of whiting in the North Sea : samples from the north were dominated by *Ceratomyxa* with 46% prevalence, compared with only 1.3% in the south, while samples from the south were dominated by *Myxidium* with 40% prevalence, compared with only 9% in the north. The cnclusion was that there were two distinct northern and southern populations of whiting in the North Sea with a small area of mixing between them.

Myxosporean parasites have a number of features which make them attractive candidates for use as tags : infections appear to be of long duration, possibly lasting for the entire life span of the fish host; they are easily detected and identified, usually being site-specific and with distinctive spore morphology; and they are not usually markedly pathogenic. Care must be taken, however, to note the presence of not only spores, which may only appear seasonally, but also the less obvious vegetative stages.

1.2 - Marine mammals

Balbuena and Raga [17] identified two main problems in attempting to use parasites as tags for marine mammals : large samples are difficult to obtain and sampling is often opportunistic rather than systematic. These are the same problems encountered when using parasites as tags for large valuable species of fish, so the favoured approach for such a study would be to analyse entire parasite assemblages using multivariate statistical analyses (method 2 above). This was the approach adopted by Balbuena and Raga [17] in their study of the social structure of pods of long- finned pilot whales *Globicephala melas* off the Faroe Islands. When the four most common helminth species were selected for comparisons of their levels of infection across pods, significant differences were found between pods. The authors concluded that helminth parasites have potential value as indicators in population and behavioural studies of marine mammals. Another study by Dailey and Vogelbein [18] suggested that three species of juvenile acanthocephalans of the genus *Corynosoma* could be of value in distinguishing regional stocks of sperm whales *Physeter catodon* in the Antarctic and sub-Antarctic. One species was found only in whales caught in the southern Indian Ocean, another only in whales caught in the southern Atlantic and a third only in whales caught in the southern Pacific.

1.3 - Marine invertebrates

Most biological tag studies of marine invertebrates have been carried out on cephalopods and decapod crustaceans. The excellent review of parasites as tags for cephalopods by Pascual and Hochberg [19] made the point that the main use of tag parasites is as indicators of host phenotypes rather than as indicators of genetically homogeneous stock units. Parasites can thus be used to identify subpopulations or 'ecological stocks' which cannot be distinguished by genetic/biochemical techniques. The parasite taxa which have been most frequently used as tags in population studies of cephalopods are anisakid nematiod larvae, metacestodes and larval didymozoid digeneans. The studies in which parasites have been used as biological tags in the fisheries biology of cephalopods, including stock separation, are listed by Pascual and Hochberg [19]. Thompson and Margolis [20] used differences in mean abundances of two species of digenean metacercariae to provide evidence of the existence of several discrete populations of the shrimps *Pandalus jordani* and *Pandalopsis dispar* in an inshore area of British columbia, Canada.

2 - Recruitment Studies

These studies aim to follow the migratory routes of host species from juvenile nursery areas to adult spawning and feeding areas. A parasite selected as a tag for this purpose must show the following features.

1. It must infect the young host on the nursery area and no further infection should be possible after the host has left the nursery area.
2. It must either have a long life span in the subject host or leave evidence of infection in the mature adult host (The dead remains of some parasites, particularly parasitic copepods, may be identifiable in the host long after the animal itself has died).

2.1 - Anadromous fish

parasites can be particularly useful as tags in recruitment studies of anadromous fish. Some parasites which the young fish acquire in fresh water are capable of surviving the transition from fresh to salt water.

Myxosporeans, digenean metaceracariae, metacestodes and adult nematodes have proved to be particularly useful.

A classic study of this type is that of

Mrgolis [21]. The subject host was the sockeye salmon *Oncorhynchus nerka,* which spawns in rivers on both the Asian and North American sides of the North Pacific. There is a high seas fishery for adult salmon across the North Pacific. For the management of this fishery it was important to know the oceanic range of salmon originating form each continent. Margolis found that juvenile salmon form North American rivers were infected with a metacestode which did not occur in Asian rivers. Conversely, an adult nematode infected salmon form Asian rivers but was absent from North American rivers. Comparisons of prevalences of infection of both parasites in juvenile salmon caught in rivers with those in samples of adult salmon caught at sea enabled Margolis to estimate the proportions of salmon originating form each continent in different parts of the ocean.

Margolis [22] subsequently used two species of myxosporean parasites to distinguish sockeye of different geographical origin within a single river system in British Columbia, Canada. The data were accurate enough to be used as evidence in court proceedings where a vendor was suspected of offering for sale salmon which had been caught illegally [23].

2.2 - Marine fish

MacKenzie [24] used a metacestode and two species of digenean metacercariae to follow recruitment migrations of herring *clupea harengus* L. in part of the northeast Atlantic. The two main nursery grounds for herring in the study area are Scottish coastal waters and the Bløden ground off the coast of Denmark. In Scottish coastal waters, metacercariae were found in over 70% of juvenile herring, compared with less than 1% at Bløden, while at Bløden the metacestode was found in about 10% of juvenile herring but was never found in several thousand young herring form Scottish waters. Both parasites infected herring in the first year of life after which there appeared to be no further infection and both had life spans of several years in herring. They provided a means of quantifying the proportions of recruits originating from the two nursery areas in different populations of adult herring.

2.3 - Marine invertebrates

Owens [25,26] used two parasites, an isopod and a metacestode, as biological tags for banana prawns *Penaeus mergunsis* in the Gulf of Carpetaria in northern Australia. The prawns have their nurseries in river estuaries bordering the Gulf, after which they migrate offshore and are exploited by a commercial fishery. The aim of the biological tag study was to obtain information about the extent of offshore migrations form different estuarine nurseries-information which would help with the management of the fishery. Both parasites infect juvenile prawns only in their estuarine nursery areas. Infections in samples of juvenile prawns caught in different estuaries were compared with infections in samples of juvenile prawns caught in different estuaries were compared with infections in samples of adult prawns caught on offshore grounds. These comparisons provided evidence that prawns did not migrate far from their estuaries of origin, so offshore populations originating form different estuaries tended to remain separate and did not mix to any observable extent with those from other estuaries.

3 - Seasonal Migrations

The adults of many species of marine fish make extensive seasonal migrations between feeding and spawning areas. Since the time scale of these migrations is less than one year, parasites with short life spans of less than one year are suitable as tags.

The Baltic Sea is a particularly good region for this type of study because the gradual decrease in salinity from west to east results in a parasite fauna which changes form purely marine in the west to freshwater in the east.

Some species of euryhaline fish which spawn in the Baltic comprise stocks which either migrate to the North Sea or its approaches to the Baltic (The Skagerak and kattegat) to feed, or are entirely resident in the Baltic.

During their feeding season the migratory stocks acquire infections of purely marine parasites which serve to distinguish them from the resident stocks during the spawning season. Grabda [27,28] identified migratory stocks of herring and garfish *Belone belone* by their infections with two marine parasites, a larval nematode and a metacestode. The arrival of the migratory components on spawning grounds in the southern Baltic was detected by the appearance of these marine parasites.

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