Are Naturally-Occurring Parasite "Tags" Stable? An Appraisal from Four Case Histories Involving Pacific Salmonids

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This paper summarizes the biological characteristics of naturally acquired parasites that serve as "tags" for anadromous salmonid stocks, and reviews the advantages of parasite "tags" over traditional methods of tagging or marking. Four case histories of Canadian studies on the use of freshwater parasites in Pacific salmonid stock identification are examined with respect to the annual stability of the parasite "tags." Two of these studies involve the use of parasites to determine the ocean distribution of stock groups of sockeye salmon (*Oncorhynchus nerka*) and steelhead trout (*O. mykiss*), one relates to seaward migration routes of mainly Fraser River (British Columbia) juvenile sockeye salmon, and the fourth concerns quantitative estimates of the stock composition in a mixed stock sockeye salmon fishery on the west coast of Vancouver Island, British Columbia. The conclusions reached are: (1) Where stock identification is based on the unique presence of certain heteroxenous helminth parasites, the use of such parasite "tags" usually provides a stable basis for qualitative stock identification. In these instances the presence of the parasite "tag" in a salmonid stock is dependent on the co-existence of the salmonid and one of the other essential hosts in the life cycle of the parasite; (2) where parasites are used for quantitative estimates of stock composition, baseline data may have to be re-established annually to take into account annual variations in parasite prevalence (% of stock with the parasite) and intensity (numbers of parasites in each host) among the stocks to be distinguished; and (3) some quantitative parasite differences among salmonid stocks may appear to be stable for periods up to 10 or more years, but may show marked changes over the longer term.

INTRODUCTION

The potential for using naturally-occurring parasites as "tags" or markers in Pacific salmonid stock identification was initially explored some forty years ago within the research program conducted under the auspices of the International North Pacific Fisheries Commission. The research by Canadian scientists culminated in the successful application of this technique for describing the ocean distribution of western Alaskan and Kamchatkan sockeye salmon (*Oncorhynchus nerka*) stocks (Margolis 1963). In subsequent years scientists of all four member parties of the North Pacific Anadromous Fish Commission (NPAFC) engaged in salmonid stock identification studies using parasite "tags" either alone or in combination with other stock-distinguishing characteristics. Both local and intercontinental stock differentiation problems were successfully investigated (Konovalov 1971; Awakura et al. 1982, 1995; Bugaev 1982, 1986; Butorina and Shedko 1985; Awakura 1989; Dalton 1989a, 1989b, 1991; Urawa 1989; Moles et al. 1990; Myers et al. 1991; Urawa and Nagasawa 1991, 1995; and Canadian references listed below).

Canadian research, the focus of this paper, concentrated on four studies involving sockeye salmon and steelhead trout (*Oncorhynchus mykiss*) (Margolis 1963, 1982, 1984, 1985, 1990; Quinn et al. 1987; Bailey et al. 1988, 1989; Groot et al. 1989; Beacham et al. 1997).

In the NPAFC Science Plan for 1995-96 (Anonymous, 1996), one of the questions raised concerning stock identification was: "Are baseline data (genetic, parasite, etc.) stable?"

The purpose of the present paper is to examine available data pertaining to this question with respect to the four Canadian studies.

Before examining these four case histories and the stability of the parasite tags used therein, as background it seems appropriate to list the important

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conditions that must be met to ensure the usefulness of a parasite as a tag for fish population studies, and to review the advantages of parasite tags over conventional tagging and marking methods that generally have been used in such studies.

There are at least three general conditions that must be met to ensure the usefulness of a parasite as a population tag. These are:

1. The parasite must be present in one stock or group of stocks, and absent or rare in others from which it is to be distinguished, or it must occur in markedly different numbers in the stocks to be distinguished;

2. It is essential that the parasite have a long life span, preferably as long as that of its host, or at least as long as that period of the host's life over which observations on the stock are being made; and

3. The parasite should have a negligible effect on survival and behaviour of the host.

For anadromous salmonids, the important criteria may be listed as follows:

1. The parasite should have a freshwater life cycle, with no transmission or inter-host transfer at sea;

2. A restricted freshwater distribution within the range of the salmonid host; and

3. A long life span, including survival during all or part of the marine life of the salmonid host.

Advantages of parasite tags are:

1. A much larger proportion (sometimes all) of the stock may be marked naturally by a particular parasite than is usually possible when applying artificial tags or marks, at least for wild fish populations;

2. The fish do not have to be handled to apply the tag or mark, thus eliminating so-called "tagging" or "marking" mortality and possible influences on migratory or other behaviour; and

3. The fish need only be caught once to derive information about its origins, migrations, or stock affinities, whereas in conventional tagging and marking the fish must be caught to be tagged or marked, returned to the water, and recaptured a second time.

Although these advantages of parasite tags are evident, it is clear that parasites are not a panacea for solving all stock identification problems, but when appropriate differences exist, this technique can be a powerful tool in stock identification.

Comparison of the parasite-tag method of stock identification with that of the newer genetic techniques is discussed in Beacham et al. (1998) in this volume.

CASE HISTORIES

Case History 1

The first case history to be discussed is that in which two freshwater parasites were used to define the ocean distribution of North American and Asian sockeye salmon (Margolis 1963). In this study, the occurrence of the plerocercoid (or juvenile) stage of the tapeworm *Triaenophorus crassus* in the somatic musculature and the presence of the nematode *Truttaedacnitis truttae* in the intestine were used to identify the ocean distribution of western Alaskan (essentially Bristol Bay) and Kamchatkan sockeye salmon, respectively (Fig. 1). Both parasites are acquired in fresh water and apparently survive throughout the marine life of sockeye salmon.

The obligatory definitive host of *T. crassus* is the northern pike, *Esox lucius*. Sockeye salmon become infected with the juvenile tapeworm only in lakes where pike and sockeye salmon are sympatric, such as occurs in western Alaska. Therefore, as a tag identifying the western Alaskan origin of sockeye salmon, *T. crassus* would be stable unless pike carrying the adult tapeworm were to be introduced into other watersheds where sockeye salmon occur.

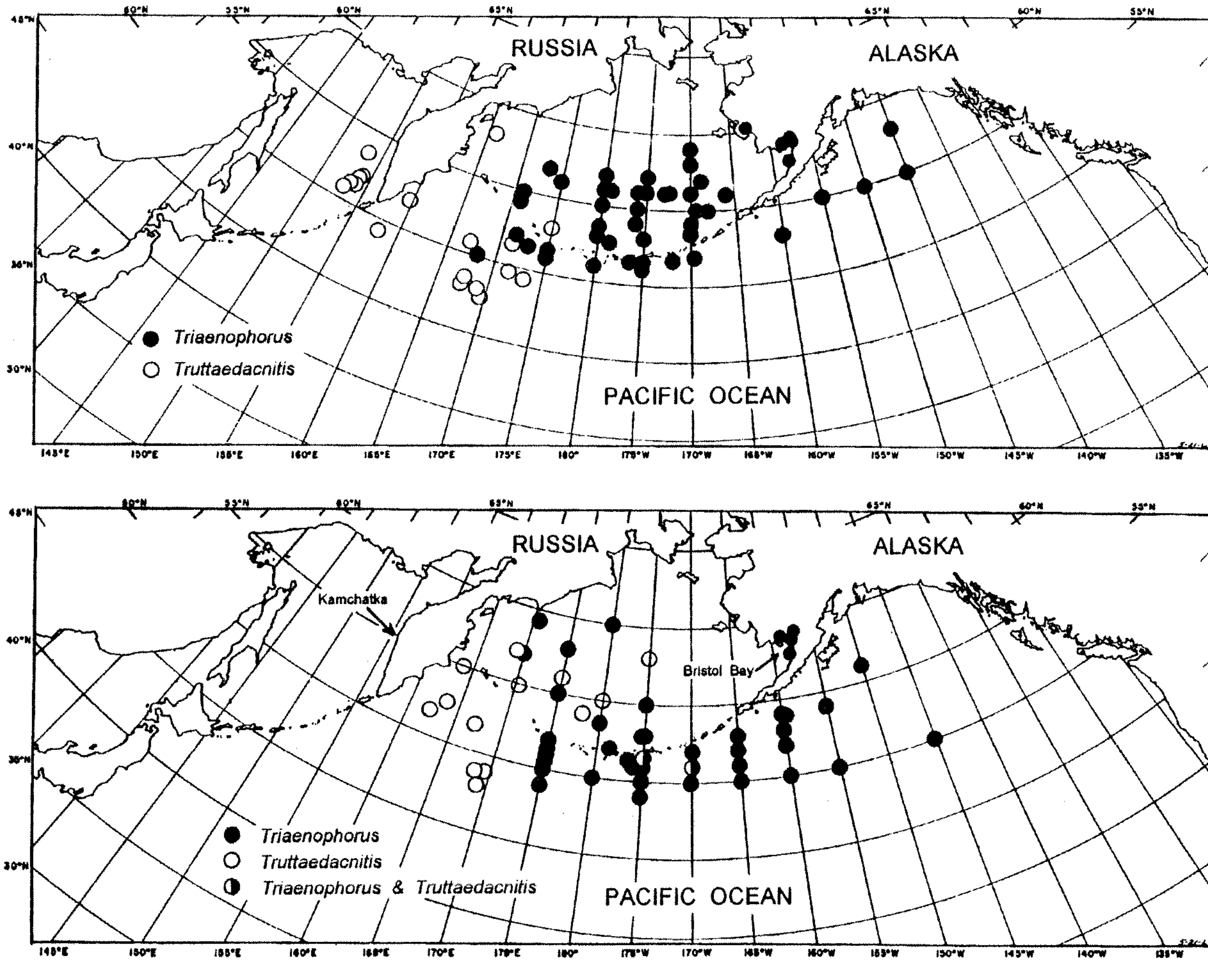
It has been proposed that the prevalence of *T. crassus* can be used to estimate proportions of Bristol Bay sockeye salmon in offshore samples (Margolis 1963). However, the prevalence of the plerocercoids in Bristol Bay sockeye salmon is highly variable annually (Table 1), requiring that the baseline data be re-established annually. In this sense, for quantitative estimates of stock composition, *T. crassus* is clearly unstable.

Table 1. Estimated prevalence of *Triaenophorus crassus* plerocercoids in Bristol Bay adult sockeye salmon (*Oncorhynchus nerka*), 1957-1959 (from Margolis, 1963).

Year	Prevalence (%)
1957	3.2
1958	22.0
1959	10.6-13.3

The life history of *T. truttae* remains unclear but it is apparently a stream rather than lacustrine parasite and hence would only occur in sockeye salmon stocks that rear in streams. Insufficient knowledge about the biology of *T. truttae* in Kamchatka precludes commenting definitively on the stability of this nematode as a tag. All that can be said is that it has not been reported from North American sockeye salmon, suggesting that it is a stable qualitative tag for Kamchatkan sockeye salmon.

Fig. 1. Ocean distribution of western Alaskan and Kamchtkan sockeye salmon (*Oncorhynchus nerka*) as determined by the occurrence of *Triaenophorus crassus* and *Truttaedacnitis truttae*, respectively, in samples from the North Pacific Ocean and adjacent seas, 1955-1959. Upper chart, maturing fish; lower chart, immature fish. (Adapted from Margolis, 1963.)



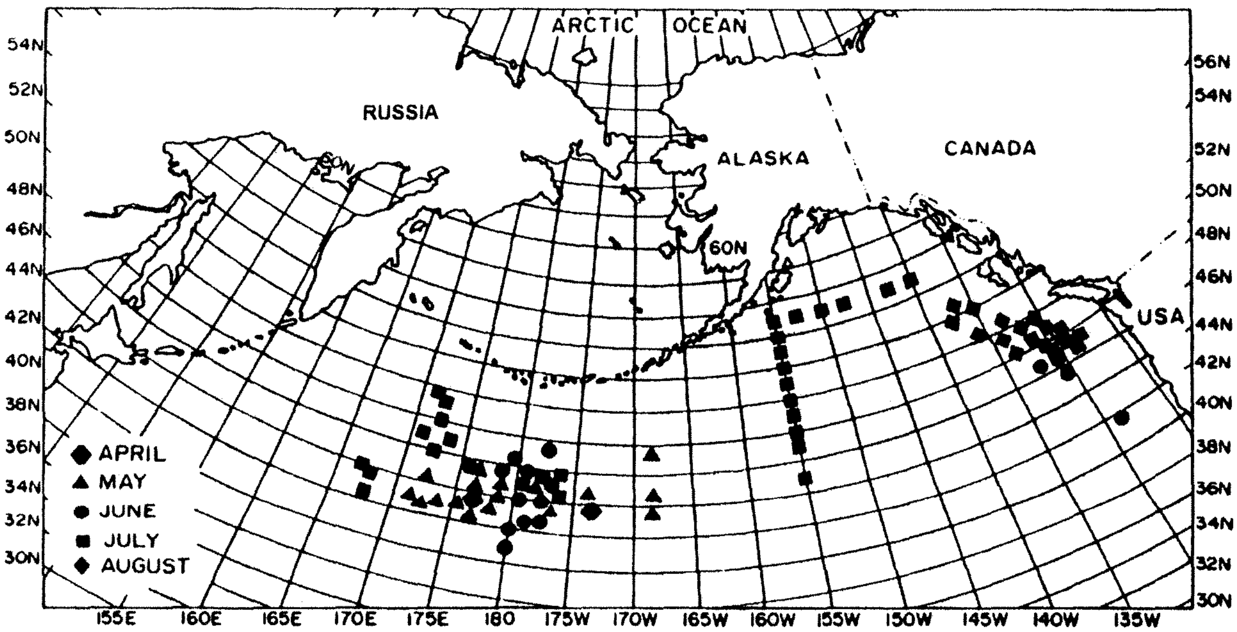
Case History 2

The second case history revolved around the use of two freshwater trematode parasites (*Nanophyetus salmincola* and *Plagioporus shawi*) to identify the ocean range (Fig. 2) of steelhead trout originating from the northwestern part of the United States, from northern California to northern Washington and including Idaho (Margolis 1984, 1985, 1990; Dalton 1989a, 1989b; Burgner et al. 1992). *Nanophyetus salmincola* occurs as a juvenile or metacercaria encysted in various tissues or organs, particularly the kidney, and *P. shawi* occurs as an adult in the intestine. Both parasites are acquired in fresh water and apparently many, if not all, *N. salmincola* survive through the marine life of the anadromous host. An undetermined proportion of *P. shawi* seem to perish at sea.

The freshwater distribution of these two parasites is governed by the distribution of their obligatory first intermediate snail hosts, *Juga* spp. for *N. salmincola* and *Fluminicola virens* for *P. shawi*. Steelhead trout and these snail hosts are sympatric only in the U.S. northwestern states previously mentioned, accounting for the restricted freshwater distribution of infected steelhead trout. The other hosts in the life cycle (Margolis 1984, 1985, 1990) are not specific and hence are not limiting factors in the freshwater distribution of these parasites.

The possibility of using prevalence data on *N. salmincola* and *P. shawi* to estimate proportions of U.S. Pacific Northwest steelhead trout in high-seas samples was first recognized by Margolis (1984, 1985) and pursued by Dalton (1989a, 1991) using data on *N. salmincola* only. However, annual changes in prevalence of *N. salmincola* and in the relative

Fig. 2. Ocean distribution of U.S. Pacific Northwest steelhead trout (*Oncorhynchus mykiss*) as determined by the presence of *Nanophyetus salmincola* and/or *Plagioporus shawi* in samples from the North Pacific Ocean, 1983-1987. (Adapted from Margolis, 1982.)



abundance of the many steelhead trout stocks complicated this attempt to quantify the representation of steelhead trout from the *N. salmincola*-endemic area in high-seas samples.

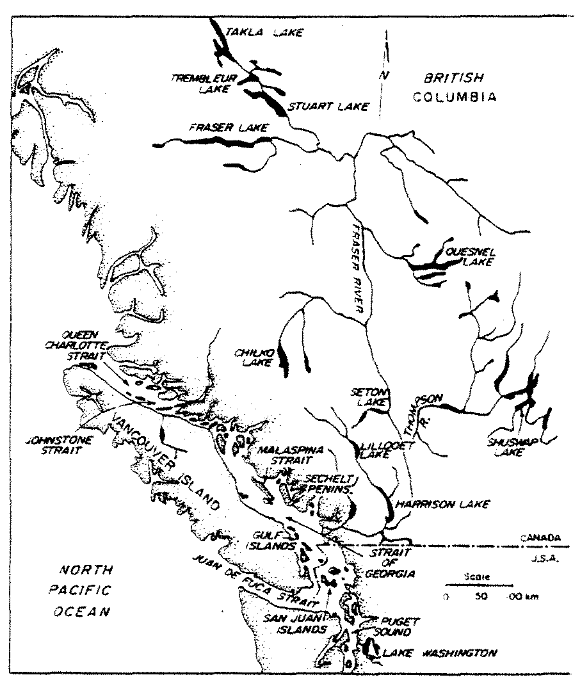
Like the previous case on sockeye salmon, for qualitative description of the oceanic range of U.S. Pacific Northwest steelhead trout, the two trematode tags may be considered stable, unless the distributions of the obligatory snail hosts are expanded beyond the U.S. Pacific Northwest through human activities. For quantitative estimates of stock composition, the parasites must be classified as unstable because of annual changes in prevalence.

Case History 3

In this case history, stock differences in an assemblage of 12 freshwater parasites were used to estimate the stock composition of juvenile sockeye salmon migrating seaward through the Strait of Georgia, British Columbia (Bailey et al. 1988; Groot et al. 1989). These sockeye salmon originate primarily from various tributaries of the Fraser River and from Lake Washington (Fig. 3).

The data on differences in parasite prevalence, intensity, or abundance (see Margolis et al. 1982 for definitions) were analyzed using the maximum-likelihood mixture model (Fournier et al. 1984; Wood et al. 1987). Although this approach proved to

Fig. 3. Principal sockeye salmon (*Oncorhynchus nerka*) lakes of the Fraser River system, British Columbia, and Puget Sound, Washington. (From Groot et al., 1989.)

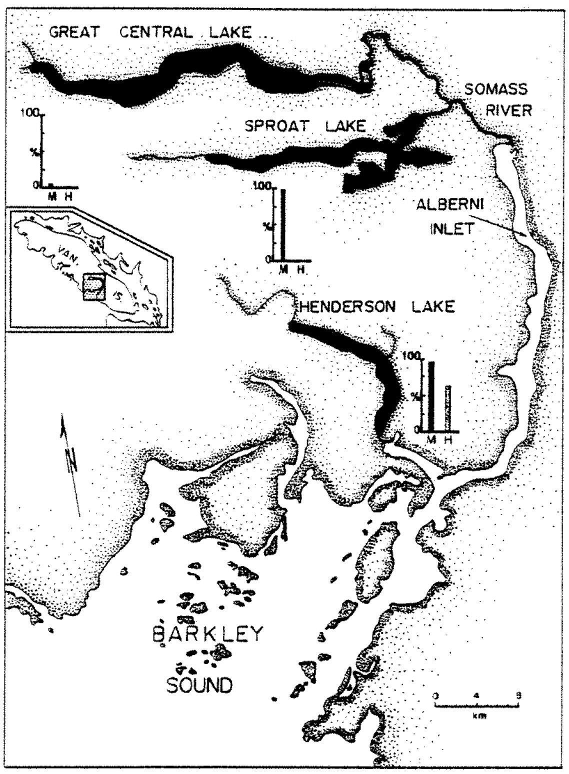


be an effective method of stock identification it was clear that in the three years of study, 1982-1984, the abundance of many of the parasites used in the analysis varied markedly by year, requiring the baseline data to be re-established annually, again indicating quantitative instablility in the parasite tags.

Case History 4

Case history 4 is perhaps the most interesting of all from the point of view of stability of parasite tags. In this example, three sockeye salmon stocks in Barkley Sound (west coast of Vancouver Island, British Columbia) are the subject of a mixed stock fishery. The three stocks are associated with Great Central Lake, Sproat Lake, and Henderson Lake (Fig. 4).

Fig. 4 Barkley Sound, Vancouver Island, area, showing the three sockeye salmon (*Oncorhynchus nerka*) producing lakes and prevalences of *Myxobolus arcticus* and *Henneguya salminicola.*



To avoid overexploitation of individual stocks in the fishery, knowledge is required of the stock composition throughout the fishing season. During the late 1970s and in the 1980s, this was successfully accomplished by distinguishing the stocks on the basis of unique parasite characteristics in each stock (Margolis 1982). The differences involved two myxosporeans, one (*Myxobolus arcticus*) occurring in the brain, and the other (*Henneguya salminicola*) located in macroscopic "cysts" in the somatic musculature.

During the years 1977-1984, sampling of smolts and returning adults to each of the lake systems demonstrated considerable stability in the occurrence of each of the parasites in each of the stocks: Great Central Lake sockeye salmon were characterized by low prevalence of *M. arcticus* (mean $<5\%$) and *H. salminicola* ($<1\%$); Sproat Lake sockeye salmon were characterized by almost 100% prevalence of *M. arcticus* and absence of *H. salminicola*; Henderson Lake sockeye salmon were characterized by almost 100% prevalence of *M. arcticus* and 55-76% (mean 66%) prevalence of *H. salminicola* (Fig. 5). These stock characteristics were stable for approximately 10 or more years and permitted accurate estimates of the stock composition in the Barkley Sound fishery and in weekly pre-fishery forecasts.

However, baseline sampling of the three constituent stocks from 1993-1995 indicated a major change had taken place in the prevalence of both parasites in Great Central Lake sockeye salmon (Table 2), which greatly reduced the reliability of these parasites for determining stock composition of the mixed sockeye salmon population in Barkley Sound. No change in Henderson Lake sockeye salmon and minimal change of *H. salminicola* in Sproat Lake sockeye salmon occurred during this period.

This example indicates that parasite tags may be stable for a decade or more, only to undergo major changes subsequently. It is imperative, therefore, to check baseline data periodically when using parasites to estimate stock composition in mixed stock fisheries.

CONCLUSIONS

1. Where stock identification is based on the unique presence of certain heteroxenous helminth parasites, the use of such parasite "tags" usually provides a stable basis for qualitative stock identification. In these instances the presence of the parasite "tag" in a salmonid stock is dependent on the sympatric occurrence of the salmonid and one of the other essential hosts in the life cycle of the parasite.
2. When parasites are used for quantitative estimates of stock composition, baseline data may have to be re-established annually to take into account annual variations in parasite prevalence (% of stock with the parasite) and intensity (numbers of parasites in each host) among the stocks to be distinguished.
3. Some quantitive parasite differences among salmonid stocks may appear to be stable for periods up to 10 or more years, but may show marked changes over the longer term.

Fig. 5 Prevalence of *Myxobolus arcticus* and *Henneguya salminicola* in adult sockeye salmon (*Oncorhynchus nerka*) stocks from the Barkley Sound area, Vancouver Island, British Columbia, 1977-1984 combined.

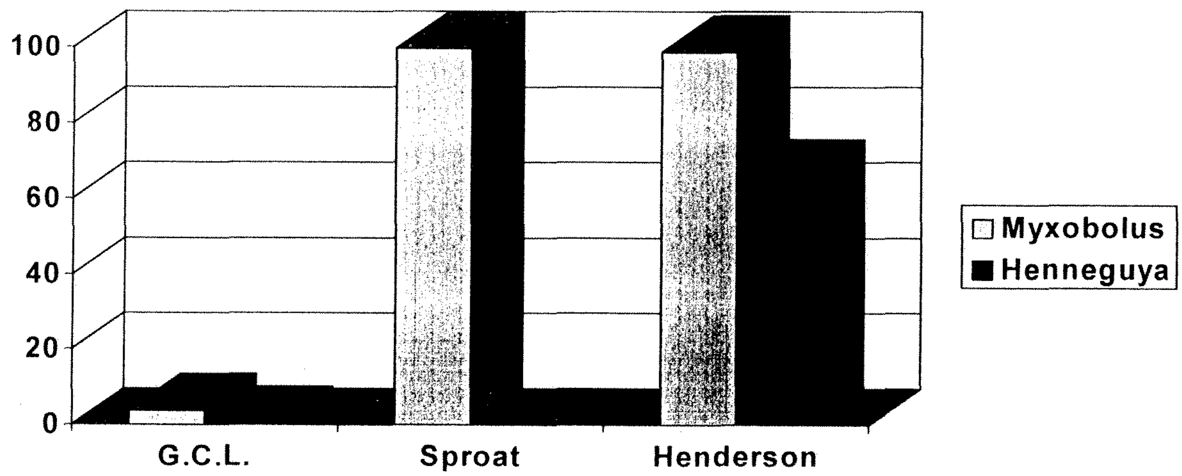


Table 2. Prevalence of *Myxobolus arcticus* (M) and *Henneguya salminicola* (H) in adult sockeye salmon (*Oncorhynchus nerka*) stocks from Barkley Sound, B.C., 1993-1995.

Year	Great Central		Sproat		Henderson	
	M	H	M	H	M	H
1993	52.4	18.7	99.7	0.0	-	-
1994	69.4	23.4	99.6	2.0	-	-
1995	75.5	19.0	100.0	0.0	100	75

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