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Parasites as Natural Tags for Marine Fish: A Review

by

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INTRODUCTION

Parasites have been used to provide information about taxonomic relationships, migrations, and intermixing of terrestrial animals, particularly birds, for almost a century. Exploration of parasitological approaches to understanding populations and movements of marine fish is of more recent origin, probably beginning with the work of Dogiel and Bykhovski (1939) who distinguished two groups of acipenserids in the Caspian Sea by parasitological methods, and in that same year the work of Herrington et al. (1939) on populations of redfish, *Sebastes marinus*, in the Gulf of Maine. The use of parasites as natural tags for fish was greatly expanded during the 1950's, and has had continuing applications ever since. During the past thirty years the utility of parasitology to fishery biological and management needs has been demonstrated for a number of economically important species -- particularly salmon and herring, but also including redfish, flounders, cod, whiting, plaice, haddock, and others. Parasites which have provided the most definitive information include the myxosporidans, encysted larval helminths, and parasitic copepods.

This paper attempts to review and assess progress to date in the application of parasitology to questions about discreteness of stocks and movements of marine and anadromous fishes. The literature is voluminous, so much of the content of this report is confined to specific examples of successful use of this approach.

The core of the paper is an attempted summarization of some of the more significant studies -- first with a table listing a large number of investigations; this is followed by a few detailed examples of successful application of the method; and, finally, case histories of parasitological studies of Pacific salmon and Atlantic herring are given.

CRITERIA FOR AN APPROPRIATE PARASITE TAG

Parasites might, on superficial examination, seem to be unlikely prospects as tags for fish. Their life cycles are often complex or still unknown; their ecology, involving one or more hosts as well as the external environment, is even more complex; and their identification is often uncertain or subject to disagreement. Despite these negative aspects, it is still possible to describe an ideal natural tag as possessing the following characteristics:

- Significant geographic variation in prevalence should exist; the parasites should be common in one population and rare in another.
- The parasite should be easily detected, preferably by gross examination.
- The parasite life cycle should preferably involve only a single host.
- Definitive identification of the parasite should be feasible.
- The parasite should have a negligible effect on survival of the host.
- Parasite prevalences should remain relatively stable from season to season or year to year.
- The parasite should persist in the host for at least the duration of the study (suggested minimum 2 years) -- and preferably longer.

A natural tag with all these attributes is of course the ideal, and is rarely achieved. Tradeoffs and compromises must be made. Less than optimum geographic differences in prevalences may not eliminate a parasite from consideration, and a complex life cycle involving more than one host may not be a basis for discounting use of larval helminths. Departure from the ideal may be offset by use of several different parasites simultaneously, and by use of appropriate multivariate statistical procedures, both in sampling design and data analysis.

ADVANTAGES OF PARASITES AS TAGS

In planning a program to elucidate populations or migrations of fish, each potential approach -- parasitological, morphometric/meristic, biochemical/serological or artificial tags -- should be examined with respect to expertise, time and funding available. The advantages of parasite tags include the following:

- The method does not induce major or traumatic external effects on the fish, since no handling is involved.
- The method can be combined with, and gains added strength from, biochemical/serological, and morphometric/meristic studies of the same samples.
- The method gains still greater strength when parasite biochemical speciation or strain differentiation is done.
- A larger proportion of the population is tagged than would be feasible with artificial tags.
- The fish needs to be caught only once.
- The cost of the study is usually less than that of a tagging program.

DISADVANTAGES OF PARASITES AS TAGS

Parasites can provide information useful to solution of biological problems, or useful to management of stocks, but limitations do exist:

- Training and background in parasitology is required of the person who plans and institutes the program.
- Extensive preliminary work is required, to identify the parasites found, to determine if geographic differences in prevalence exist, and to learn as much as possible about the ecology and life cycles of parasites selected as candidates. This phase is particularly important if the parasitology of the host fish species is poorly understood (as many are).
- Parasite tags are unsuited for study of movements of individual fish.

° Correct identification of large numbers of parasites must be made throughout the study. For some larval helminth parasites this can be a difficult and time-consuming occupation.

EXAMPLES OF SUCCESSFUL USE OF PARASITES AS TAGS

The world literature on parasites as natural tags for marine and anadromous fish is extensive, addressing many problems in many species. Table 1 summarizes a number of instances of successful application of the method to some of our most important commercial species. Of these, several seem particularly illustrative of solutions to specific problems. These are reviewed briefly in the following sections:

(1) Redfish (Sebastes marinus) stocks of the Western North Atlantic

One of the most exhaustive surveys of parasite prevalences was reported by Templeman and Squires (1960). Working exclusively with the parasitic copepod, Sphyrion lumpi, in redfish stocks, the authors found a major center of infestation off the southern Labrador coast, with lesser centers on the southeast slope of the Grand Bank and in the southeastern Gulf of St. Lawrence. In other areas the parasite was rare or absent, indicating limited intermixing. A study of residual remains of previous generations (dead encapsulated heads) in the flesh of redfish disclosed the same centers of abundance as for living copepods, except for some spreading in the direction of deep water currents.

A later and less intensive study by Sindermann (1963) using a composite of frequencies of five different parasites also suggested slight, if any, intermixing, even for stocks not widely separated geographically.

(2) Stock of Cod (Gadus morhua) in the Western North Atlantic

Early tagging studies (Schroeder, 1930; Wise, 1958) indicated a discrete self-contained stock of cod in the area south of Nantucket, but other groups were less clearly defined. Using a common parasitic copepod, Lernaeocera branchialis, Sherman and Wise (1961) were able to confirm the discreteness of the southern New England population, free of infestation by the parasite. An increasing gradient of prevalences extended northward. Light infestation on Georges Bank indicated little mixing with the southern population or with those to the north, where prevalences were much higher.

(3) Differentiation of North Sea Whiting (Merlangius merlangus) Stocks

Two species of gall bladder inhabiting myxosporidans, Ceratomyxa arcuata and Myxidium sphaericum, were used by Kabata (1959, 1963, 1967) to distinguish northern and southern stocks of North Sea whiting. Fish north of 56°N had predominant infections with Ceratomyxa, while those south of 54°N were infected mainly with Myxidium. The zone of overlap (54°N to 56°N) which includes the Dogger Bank was delineated by intermediate prevalences of both parasites. The parasitological evidence also indicated the existence of a distinct whiting population in the Irish Sea.

A later study (Hislop and MacKenzie, 1976) using conventional tags and the distribution of a larval cestode, Gilquinia squali, in the eyes of whiting, suggested further subdivision of the northern stock into Scottish coastal, offshore, and Shetland groups.

(4) Recruitment Migrations of North Sea Herring (Clupea harengus)

MacKenzie and Johnston (1976) used the prevalences of three parasites -- two trematodes and a cestode, to determine recruitment migrations of autumn spawned North Sea herring. Herring from the Minch showed changes with age consistent with continuous immigration from Bløden. The authors found, using the parasite frequencies, that the proportion of immigrants built from about 40% in the 2-group to over 80% in the 4+ group.

(5) Identification of Fishing Zone of Sole (Solea solea)

An interesting case in which the distribution of a parasite in a by-catch species was used to determine the fishing zone for a principal species was reported by van Banning et al. (1978). To identify catches of sole, (Solea solea) as coming from an area of the North Sea under quota regulations or from the free area of the Skagerak, parasites of plaice (Pleuronectes platessa), landed as bycatch with the sole, were examined. A protozoan parasite, Myxobolus aeglefini, was found in high prevalences in plaice from the Skagerak, but was very rare in plaice from the North Sea. The minimal intermixing of plaice substocks in the North Sea and adjacent waters was indicated by data collected during the period 1973-1978.

(6) Subgroups of Baltic cod (Gadus morhua callarias)

Prevalences of two larval anisakid nematodes, Anisakis simplex and Contracaecum aduncum, were used by Grabda (1976) to differentiate three groups of Baltic cod -- those from the western Baltic (Pomeranian Bay and adjacent waters), those of the central Baltic, and those of the eastern Baltic. Anisakis prevalence decreased from west to east (to zero in Gdansk Bay), while Contracaecum increased from west to east. The differential distribution of Anisakis was attributed to spawning migrations of heavily infected western herring entering the Baltic; most herring stay in Pomeranian Bay, but some migrate further eastward.

A CASE HISTORY -- HIGH SEAS MIGRATIONS OF PACIFIC SALMON

From the data contained in Table 1, it can be seen that parasite tags have been used extensively in studies of Pacific and Atlantic salmon. Some of the problems with biology and management of these anadromous species for which parasites have provided useful data include identification of the continent and even the spawning areas of juvenile and maturing fish caught at sea, and identification of tributaries of origin of mixed stocks in downstream waters.

A major multinational investigation of geographic origins and migrations of Pacific salmon, particularly sockeye salmon (Oncorhynchus nerka) was conducted during the later 1950's.

In studies which extended across the entire North Pacific, in connection with international treaty negotiations, Margolis (1956, 1963, 1965) was able to demonstrate conclusively the extent of ocean migrations and the intermixing zone of salmon of North American and Asiatic origin. Using two freshwater parasites -- the plerocercoid larva of the cestode Triaenophorus crassus which occurs in the musculature, and adult nematodes Dacnitis truttae from the intestine -- he was able to draw specific conclusions (which were substantiated by results of other studies):

- The larval tapeworm Triaenophorus was found in downstream migrant sockeye only from some western Alaska river systems, and is not acquired at sea.
- The nematode Dacnitis occurred only in rivers on the coasts of Kamchatka, and was not found in North America.
- Maturing and immature sockeye migrated up to 1700 miles from Bristol Bay.
- An intermixing zone in the central North Pacific, where

both parasites were found, was located between 170°W and 170°E.

- The prevalence of <u>Triaenophorus</u> in high seas samples of maturing fish and in samples from fish returning to spawn in Bristol Bay streams permitted estimates of relative proportions of Bristol Bay stocks in the high seas fisheries.

This study, undoubtedly a classic of its genre, provided an early and robust demonstration of the utility of parasite tags.

A CASE HISTORY -- NORTHWEST ATLANTIC HERRING STOCKS

The distribution of herring in the western North Atlantic extends from Cape Hatteras to Greenland, with a number of centers of abundance (so-called stocks or stock-complexes) (Figure 1). Two of these -- Georges Bank and Gulf of Maine -- are in United States waters, while a third -- southern Nova Scotia -- is thought to contribute to catches in the Gulf of Maine. The stocks can best be described at spawning time, since there is some evidence for intermixing and migrations at other times of the year. A variety of methods -- morphometrics and meristics, age and growth comparisons, tagging, and biological tags (biochemical and parasite) -- have been used for three decades to provide information about stock separation and movements of the various stocks. Questions still remain.

Early studies of parasites of adult herring (Sindermann, 1957a, 1961) disclosed two encysted larval helminths -- a trypanorhynchan cestode and an anisakid nematode -- with geographic variations in abundance. The larval cestode was relatively abundant in Georges Bank and southern New England samples, rare in Nova Scotia samples, and absent in the Gulf of St. Lawrence. Conversely, the larval nematode was much more abundant in Nova Scotia samples than in Georges Bank and southern New England -- indicating only limited interchange between the two areas.

Subsequent studies of the larval nematode (Boyar and Perkins, 1971; Parsons and Hodder, 1971b; Lubieniecki, 1973) demonstrated its utility. Boyar and Perkins found that during eight years of sampling (1962-1969) the worms were at least twice as abundant in samples from Nova Scotia as they were in samples from Georges Bank and the coastal Gulf of Maine, and were more abundant in coastal Gulf of Maine samples than in Georges Bank samples (Figure 2). Lubieniecki found lower nematode incidences in samples from the Middle Atlantic Bight than those reported from more northern waters of Nova Scotia and Newfoundland. Parsons and Hodder found that the nematode was more abundant in Nova Scotia and Banquereau samples than in those from the southwestern Newfoundland and the southern Gulf of St. Lawrence. Similarities in incidences between winter samples from southwestern Newfoundland and spring-autumn samples from the southern Gulf of St. Lawrence were considered to be supporting evidence that the fish form part of a single stock complex, as did similarities in incidences between northeastern Nova Scotia samples and those from the Banquereau-Cape Sable area.

While there are persistent problems, which are now being addressed by cooperative United States/Canadian investigations, parasites have provided substantive information on stocks of adult herring.

In addition to these detailed and continuing studies of adult herring, parasites have provided information about movements of juvenile herring on the Maine coast. Two parasites, the myxosporidan Kudoa clupeidae, which produces intramuscular cysts, and the larval nematode Anisakis sp., have indicated very limited eastward movement of juveniles which had spent their first year of life on the western Maine coast, with possibly greater movement westward of fish which had spent their first year on the eastern Maine coast (Sindermann, 1957a, 1957b). Subsequent tagging studies have also indicated limited movements of juveniles (Chenoweth et al., 1980).

CONCLUSIONS

After three decades of research exploring the use of parasites as natural tags for marine fish -- conducted in the Atlantic and Pacific oceans with a number of commercial species -- the utility of the method has been demonstrated adequately. Like any method of stock discrimination, the value of the approach is enhanced by simultaneous application of other methods, such as artificial tags, morphometric/meristic comparisons, age and growth studies, and biochemical/serological examinations. Parasite tags have particular value when the distribution and abundance of several different and persistent parasites can be studied over an extended period of time, and when concurrent life history and ecological studies can be conducted. In a number of studies using more conventional as well as parasitological approaches, the parasite data has frequently been of great value to conclusions reached.

REFERENCES

Arntz, W. E. 1972. On the occurrence of the parasitic copepod Lernaeocera branchialis in Kiel Bay and its significance as a biological tag. Arch. Fischereiwiss. 23, 118-127.

Arthur, J. R. and H. P. Arai. 1980a. Studies on the parasites of Pacific herring (Clupea harengus pallasi Valenciennes): survey results. Can. J. Zool. 58: 64-70.

________________ 1980b. Studies on the parasites of Pacific herring (Clupea harengus pallasi Valenciennnes): A preliminary evaluation of parasites as indicators of geographical origin for spawning herring. Can. J. Zool. 58: 521-527.

Beverley-Burton, M., O. L. Nyman and J. H. C. Pippy. 1977. Morphology and some observations on the population genetics of Anisakis simplex larvae (Nematoda: Ascaridata) from fishes of the North Atlantic. J. Fish. Res. Bd. Can. 34: 105-112.

Beverly-Burton, M. and J. H. C. Pippy. 1977. Morphometric variations among larval Anisakis simplex (Nematoda: Ascaridoidea) from fishes of the North Atlantic and their use as biological indicators of host stocks. Environ. Biol. Fishes 2: 309-314

Bishop, Y. M. M. and M. Margolis. 1955. A statistical examination of Anisakis larvae (Nematoda) in herring (Clupea pallasi) of the British Columbia Coast. J. Fish. Res. Bd. Can. 12, 571-592.

Boyar, H. C. and F. E. Perkins. 1971. The occurrence of a larval nematode (Anisakis sp.) in adult herring from ICNAF subareas 4 and 5, 1962-1969. ICNAF Res. Doc. 71-99, 2 p.

Chenoweth, S., M. Hunter and G. Speirs. 1980. Seasonal migrations and recruitment patterns of juvenile herring in the Gulf of Maine. Maine Dept. Nat. Resources, Res. Ref. Doc. 80/14, 16 pp.

Davey, J. T. 1971. A revision of the genus Anisakis Dujardin, 1845 (Nematoda: Ascaridata). J. Helminth. 45: 51-72

__________ 1972. The incidence of Anisakis sp. larvae (Nematoda: Ascaridata) in the commercially exploited stocks of herring (Clupea harengus L., 1758) (Pisces: Clupeidae) in British and adjacent waters. J. Fish. Biol. 4: 535-554.

Dogiel, V. A. 1958. Parasite fauna and its environment. Some problems of the ecology of the parasites of freshwater fishes. In Dogiel, V. A., Petrushevski, G. K. and Polyanski, Yu. I., Parasitology of Fishes, Leningrad Univ., 363 pp. (In Russian).

Dogiel, V. A. and B. E. Bykhovski. 1939. Parasites of fishes of the Caspian Sea (In Russian). Trudy kompleks. Izuch. Kasp. Morya 7: 25-62.

Gibson, D. I. 1972. Flounder parasites as biological tags. J. Fish. Biol. 4: 1-9.

Grabda, J. 1976. The occurrence of Anisakid nematode larvae in Baltic cod (Gadus morhua callarias L.) and the dynamics of their invasion. Acta Ichthyol. Pisc. 6(1): 3-22.

Hare, G. M. and M. D. B. Burt. 1975. Identification, host sites, and biology of parasites infecting juvenile Atlantic salmon (Salmo salar) in the Miramichi River system. New Brunswick. Fish. Mar. Serv. Res. Dev. Tech. Rep. 581: 34 pp.

Hare, G. M. and M. D. B. Burt. 1976. Parasites as potential biological tags of Atlantic salmon (Salmo salar) smolts in the Miramichi River system, New Brunswick. J. Fish. Res. Bd. Can. 33: 1134-1143.

Herrington, W. C., H. M. Bearse and F. E. Firth. 1939. Observations on the life history, occurrence and distribution of the redfish parasite Sphyrion lumpi. US Bur. Fish., Spec. Sci. Rept. No. 5, 18 pp.

Hislop, J. R. G. and K. MacKenzie. 1976. Population studies of the whiting Merlangius merlangus (L.) of the northern North Sea. J. Cons. Int. Explor. Mer, 37: 98-111.

Hodder, V. M. and L. S. Parsons. 1970. A comparative study of herring taken at Magdalen Islands and along southwestern Newfoundland during the 1969 autumn fishery. Annu. Meet. int. Comm. Northw. Atlant. Fish., 1970. Res. Doc. No. 77, Serial No. 2425 (mimeographed).

__________ 1971a. Comparison of certain biological characteristics of herring from Magdalen Islands and southwestern Newfoundland. Res. Bull. Int. Comm. Northw. Atlant. Fish., No. 8, pp. 59-65.

__________ 1971b. Some biological features of southwest Newfoundland and northern Scotian Shelf herring stocks. Int. Comm. NW. Atl. Fish. Res. Bull. 8: 67-73.

Kabata, Z. 1959. Some observations on gall-bladder Protozoa in North Sea whiting. ICES CM, 1959, Near Northern Seas Committee Doc. No. 36, pp. 4-9.

__________ 1963. Incidence of coccidioses in Scottish herring (Clupea harengus L.). J. Cons. Int. Explor. Mer 28: 201-210.

__________ 1963. Parasites as biological tags. ICNAF Spec. Pub. No. 4, pp. 31-37.

__________ 1967. Whiting stocks and their gall-bladder parasites in British waters. Mar. Res. (Scotland) 1967, No. 2, 11 pp.

Lubieniecki, B. 1973. Note on the occurrence of larval Anisakis in adult herring and mackerel from Long Island to Chesapeake Bay. ICNAF Res. Bull. No. 10, pp. 79-81.

Lubieniecki, B. 1976. Aspects of the biology of the plerocercoid of Grillotia erinaceus (van Beneden, 1858) (Cestoda: Trypanorhyncha) in haddock Melanogrammus aeglefinus (L.). J. Fish. Biol. 8: 431-439.

__________ 1977. The plerocercus of Grillotia erinaceus as a biological tag for haddock Melanogrammus aeglefinus in the North Sea and Northeast Atlantic. J. Fish. Biol. 11: 555-565.

MacKenzie, K. 1968. Some parasites of 0-group plaice, Pleuronectes platessa L. under different environmental conditions. Mar. Res. Dept. Agric. Fish. Scotl. 3, 1-23.

__________ 1974. The use of parasites in tracing herring recruitment migrations., ICES CM 1974/H:31, 4 pp.

__________ 1975a. Parasites as indicators of herring migrations in the North Sea and to the north and west of Scotland. ICES CM 1975/H:42, 3 pp.

__________ 1975b. Some aspects of the biology of the plerocercoid of Gilquinia squali Fabricius, 1794 (Cestoda: Trypanorhyncha). J. Fish. Biol., 7: 321-328.

MacKenzie, K. and C. Johnston. 1976. Recruitment to the Minch herring population, as determined by the use of parasites as biological tag and a new meristic character. ICES CM 1976/H:34, 4 pp.

Margolis, L. 1956. Report on parasite studies of sockeye and pink salmon collected in 1955, with special reference to the utilization of parasites as a means of distinguishing between Asiatic and American stocks of salmon on the high seas -- a progress report on work being carried out as part of F.R.B.'s commitments to INPFC. Fish. Res. Bd. Can., Ms. Rept. No. 624. Biological Station, St. Andrews, N. B. 20 pp. (mimeo.).

Margolis, L. 1963. Parasites as indicators of the geographical origin of sockeye salmon, Oncorhynchus nerka (Walbaum) occurring in the North Pacific Ocean and adjacent seas. Int. North. Pac. Fish. Comm. Bull. 11: 107-156.

__________ 1965. Parasites as an auxiliary source of information about the biology of Pacific salmon (genus Oncorhynchus). J. Fish. Res. Bd. Can. 22: 1387-1395.

McGladdery, S. E. 1981. A survey of parasites of Northwest Atlantic herring Clupea harengus L.: a preliminary account. NAFO SCR Doc. 81/IX/124, 12 pp.

Olson, R. E. and I. Pratt. 1973. Parasites as indicators of English sole (Parophrys vetulus) nursery grounds. Trans. Am. Fish. Soc. 102: 405-411.

Parsons, L. S. and V. M. Hodder. 1971. Variation in the incidence of larval nematodes in herring from Canadian Atlantic waters. Int. Comm. N.W. Atl. Fish. Res. Bull. 8: 5-14.

__________________________ 1974. Some biological characteristics of the Fortune Bay, Newfoundland, herring stock, 1966-71. Int. Comm. N.W. Atl. Fish. Res. Bull. 10: 15-22.

Perlmutter, A. 1953. Population studies of the rosefish. Trans. N.Y. Acad. Sci., Ser. 2, 15: 189-191.

Pippy, J. H. C. 1969a. Pomphorhynchus laevis (Zoega) Müller 1776 (Acanthocephala) in Atlantic salmon (Salmo salar) and its use as a biological tag. J. Fish. Res. Bd. Can. 26: 909-919.

____________ 1969b. Preliminary report on parasites as biological tags in Atlantic salmon (Salmo salar). I. Investigations 1966 to 1968. Fish. Res. Bd. Can. Tech. Rept. 134: 44p.

Platt, N. E. 1973. The incidence of codworm in stocks of cod from Greenland and Iceland waters. ICES Demersal Fish (Northern) Comm., C.M. 1973/F:28, 5 pp.

Polyanski, Yu. I. 1955. Contributions to the parasitology of fishes of the northern seas of the U.S.S.R. Trud. zool. Inst. Akad. Nauk SSSR, 19: 5-170.

Schroeder, W. C. 1930. Migrations and other phases in the life history of the cod off southern New England. Bull. US Bur. Fish. 46: 1-136.

Scott, J. S. 1975. Geographic variation in incidence of trematode parasites of American plaice (Hippoglossoides platessoides) in the Northwest Atlantic. J. Fish. Res. Bd. Can. 32: 547-550.

Sherman, K. and J. P. Wise. 1961. Incidence of the cod parasite Lernaeocera branchialis L. in the New England area, and its possible use as an indicator of cod populations. Limnol. Oceanogr. 6: 61-67.

Shotter, R. A. 1973. A comparison of the parasite fauna of young whiting Odontogadus merlangus (L.) (Gadidae) from an inshore and an offshore location off the Isle of Man. J. Fish. Biol. 5: 185-196.

Shulman, S. S. 1954. The importance of data on parasites of fish to related disciplines. (In Russian). Trudy Problemn. Tematichesk. Soveshch. Akad. Nauk SSRF, No. 4, p. 153-162. (English Translation. F. R. B. Translation Series, No. 193).

____________ 1961. Zoogeography of parasites of U.S.S.R. freshwater fishes, p. 180-229. In V. A. Dogiel, G. K. Petrushevski, and Yu. I. Polyanski (ed.). Parasitology of fishes. Oliver and Boyd, London. (English transl.; original Russian published in 1958).

Shulman, S. S. and R. E. Shulman-Albova. 1953. Parasites of fishes of the White Sea. Moscow and Leningrad, Acad. Sci. USSR, 198 pp. (In Russian).

Sindermann, C. J. 1957a. Diseases of fishes of the western North Atlantic V. Parasites as indicators of herring movements. Maine Dept. Sea and Shore Fish. Res. Bull. No. 27. 30 pp.

Sindermann, C. J. 1957b. Diseases of fishes of the western North Atlantic. VI. Geographic discontinuity of myxosporidiosis in immature herring from the Gulf of Maine. Maine Dept. Sea and Shore Fish. Res. Bull. No. 29. 20 pp.

______________ 1959. Population studies of herring using parasitological and serological methods. Int. Pass. Fish. Bd., Rept. Int. Joint Comm., 4: 1-15.

______________ 1961. Parasite tags for marine fish. J. Wildl. Mgmt. 25: 41-47.

______________ 1963. Parasitological tags for redfish of the western North Atlantic. ICNAF Spec. Pub. No. 4, pp. 111-117.

______________ 1965. Effects of environment on several diseases of herring from the western North Atlantic. ICNAF Spec. Pub. No. 6, pp. 603-609.

Smith, J. W. 1972. The occurrence of Diclidophora esmarkii (Monogenea) on Norway pout Trisopterus esmarkii (Nilsson, 1855) in the northern North Sea and to the north and west of Scotland. J. Cons. perm. int. explor. Mer. 34; 256-261.

Stunkard, H. W. and F. E. Lux. 1965. A microsporidian infection of the digestive tract of the winter flounder, Pseudopleuronectes americanus. Biol. Bull. 129: 371-387.

Templeman, W. and H. J. Squires. 1960. Incidence and distribution of infestation by Sphyrion lumpi (Kroyer) on the redfish, Sebastes marinus (L.) of the western North Atlantic (1949-1953). J. Fish. Res. Bd. Can. 17: 9-31.

Uzmann, J. R., R. H. Lander, and M. N. Hesseshoft. 1957. Parasitological methods for identification and abundance estimates of downstream migrant races of salmon. (Abstract). Proc. Alaskan Sci. Conf. 8: 93-94.

van Banning, P. and H. B. Becker. 1978. Long-term survey data (1965-1972) on the occurrence of Anisakis larvae (Nematoda: Ascaridida) in herring. Clupea harengus L. from the North Sea. J. Fish. Biol. 12: 25-33.

van Banning, P., J. F. deVeen and P. I. van Leeuwen. 1978. The myxosporidan parasite Myxobolus aeglefini Auerbach, 1906, and its use as a parasitological tag for plaice of the eastern North Sea. ICES CM 1978/G: 48, 8 pp.

van den Broek, W. L. F. 1979. Infection of estuarine fish populations by Cryptocotyle lingua (Creplin). J. Fish. Biol. 14: 395-402.

Wise, J. P. 1958. The world's southernmost indigenous cod. J. Cons. Int. Explor. Mer 23: 208-212.

Table 1. A SUMMARY OF SELECTED STUDIES WHICH USED PARASITES AS NATURAL TAGS

FISH SPECIES	GEOGRAPHIC AREA	PARASITE TAG(S)	SIGNIFICANT FINDINGS	AUTHOR(S)
Atlantic herring (*Clupea harengus*)	North Sea	*Anisakis* larvae	Increase in prevalence 1966-1968, and decrease 1969-1972, possibly due to change in migration behavior	Van Banning and Becker (1978)
	North Sea	*Lacistorhynchus* (cestode) *Renicola* (trematode metacercariae)	Distinguished juvenile autumn spawned herring populations from Bløden and Scottish coastal waters	MacKenzie (1974)
	North Sea	*Lacistorhynchus* (cestode) *Renicola* (trematode metacercariae)	Traced recruitment migrations of autumn spawned herring in the North Sea and to the north and west of Scotland	MacKenzie and Johnston (1976)
	North Sea	*Eimeria sardinae* and *E. clupearum* (coccidians)	Incidence of the coccidians was found to be uniform, with no significant differences in various parts of the North Sea and the west coast of Scotland	Kabata (1963)
	Middle Atlantic coast of United States	*Anisakis* larvae	Lower levels of infestation in samples from Long Island to Chesapeake Bay than in areas to the north	Lubieniecki (1973)
	Northwest Atlantic	*Anisakis* larvae	*Anisakis* increases in prevalence with increasing latitude. Georges Bank herring have lowest prevalences whereas Nova Scotia herring have the highest	Boyar and Perkins (1971)
	Canadian Atlantic waters	*Anisakis* larvae	Gulf of St. Lawrence/ Southwest Newfoundland stocks probably do not intermingle with northeastern Nova Scotia/ Banquerean Sable Island stocks	Parsons and Hodder (1971)
	Western North Atlantic	*Anisakis* larvae Trypanorhynch (cestode) larvae	Results indicate lack of intermingling of Gulf of St. Lawrence and Gulf of Maine herring	Sindermann (1957, 1961)
Pacific herring *Clupea harengus pallasi*	Coastal waters of Washington, British Columbia and Alaska	*Anisakis simplex* *Thynnascaris adunca* trematode metacercariae (Bucephalidae)	Reliable separation of adjacent spawning stocks could not be accomplished	Arthur and Arai (1980)

Table 1 - Continued

FISH SPECIES	GEOGRAPHIC AREA	PARASITE TAG(S)	SIGNIFICANT FINDINGS	AUTHOR(S)
Sockeye salmon *Oncorhynchus keta*	North Pacific	*Triaenophorus crassus* (larval cestode) *Dacnitus truttae* (adult nematode)	Distinguished maturing and juvenile high seas salmon of Asiatic and North American origin	Margolis (1959, 1963, 1965)
Atlantic salmon (*Salmo salar*)	North Atlantic	*Pomphorhynchus laevis* (acanthocephalan)	The parasite was useful in indicating tributary of origin of salmon smolts in several Irish rivers, but utility in determining continent of origin of West Greenland high seas stocks not established	Pippy (1969)
	North Atlantic	*Anisakis simplex*	Biochemical genetic studies of the nematode larvae suggested that different populations occur in fish from widely separated North Atlantic sampling sites	Beverley-Burton et al. (1977)
	Miramichi River, New Brunswick	*Discocotyle sagittata* (monogenetic trematode) *Diplostomum spathaceum* (digenetic trematode) *Neoechinorhynchus rutili* (acanthocephalan)	Tributary of origin of smolts was indicated by parasite frequencies	Hare and Burt (1976)
Whiting (*Merlangius merlangius*)	North Sea and British coastal waters	*Ceratomyxa arcuata* *Myxidium sphaericum* (myxosporidans)	Whiting stocks of the North Sea consist of two distinct populations, northern and southern. Whiting stocks to the west of the British Isles also consist of two stocks, but the Irish Sea has a separate stock	Kabata (1959, 1963, 1967)
	Northern North Sea	*Gilquinia squali* (cestode)	The northern North Sea stocks of whiting could be separated into three component -- coastal, offshore, and Shetland Islands	Hislop and MacKenzie (1976)
Haddock (*Melanogrammus aeglefinus*)	North Sea and Northeast Atlantic	*Grillotia erinaceus* (cestode)	A number of haddock subgroups was distinguished: two at Faroe, three to the north and west of Scotland, and four in the North Sea. Results suggest a northward movement of haddock along the Scottish east coast	Lubieniecki, (1976, 1977)

Table 1 - Continued

FISH SPECIES	GEOGRAPHIC AREA	PARASITE TAG(S)	SIGNIFICANT FINDINGS	AUTHOR(S)
Redfish (*Sebastes marinus*)	Western North Atlantic	*Sphyrion lumpi* (copepod)	Major centers of infestation were off southern Labrador, southeast slope of Grand Bank and southeastern Gulf of St. Lawrence; the parasite was scarce or absent elsewhere in the sampling area (exclusive of the Gulf of Maine)	Templeman and Squires (1960)
	Western North Atlantic	*Sphyrion lumpi* (copepod)	High infestation in the western Gulf of Maine, but no infestation on Browns Bank, suggesting absence of substantial movement to that Bank	Herrington et al. (1939) Perlmutter (1953)
	Western North Atlantic	*Sphyrion lumpi* (copepod) *Chondracanthopsis nodosus* (copepod) *Anisakis* larvae Trypanorhynch larvae (cestode)	Each major redfish fishing area was discrete in terms of composite parasite frequencies, suggesting absence of significant intermixing of stocks	Sindermann (1963)
Plaice (*Pleuronectes platessa*)	Eastern North Sea	*Myxobolus aeglefini* (myxosporidan)	The parasite was abundant in plaice from the Skagerak, but absent or rare in adjacent waters exploited by the Dutch fishery	van Banning et al. (1978)
Cod (*Gadus morhua*)	Northwest Atlantic	*Lernaeocera branchialis* (copepod)	Prevalence of the parasite enabled identification of four subgroups of cod -- northern Gulf of Maine, southern Gulf of Maine, Georges Bank, and southern New England	Sherman and Wise (1961)
Winter flounder (*Pseudopleuronectes americanus*)	Northwest Atlantic	*Glugea stephani*	Winter flounder from Georges Bank are geographically isolated from those on inshore grounds	Stunkard and Lux (1965)

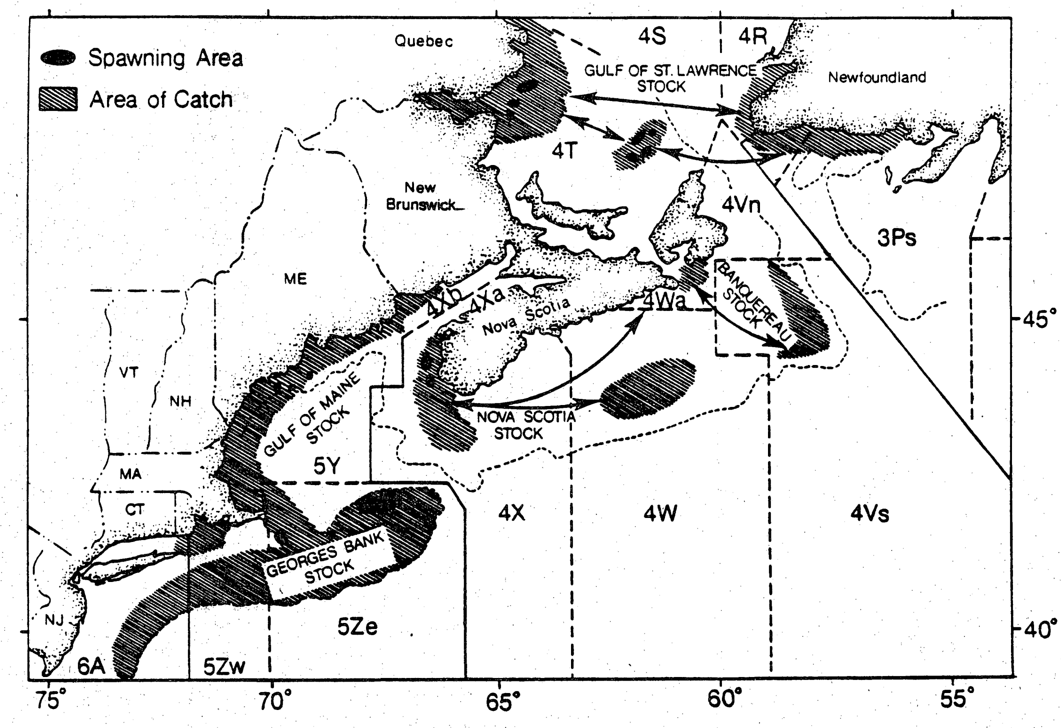

Figure 1. Centers of herring abundance in the western North Atlantic (redrawn from Anthony, 1977).

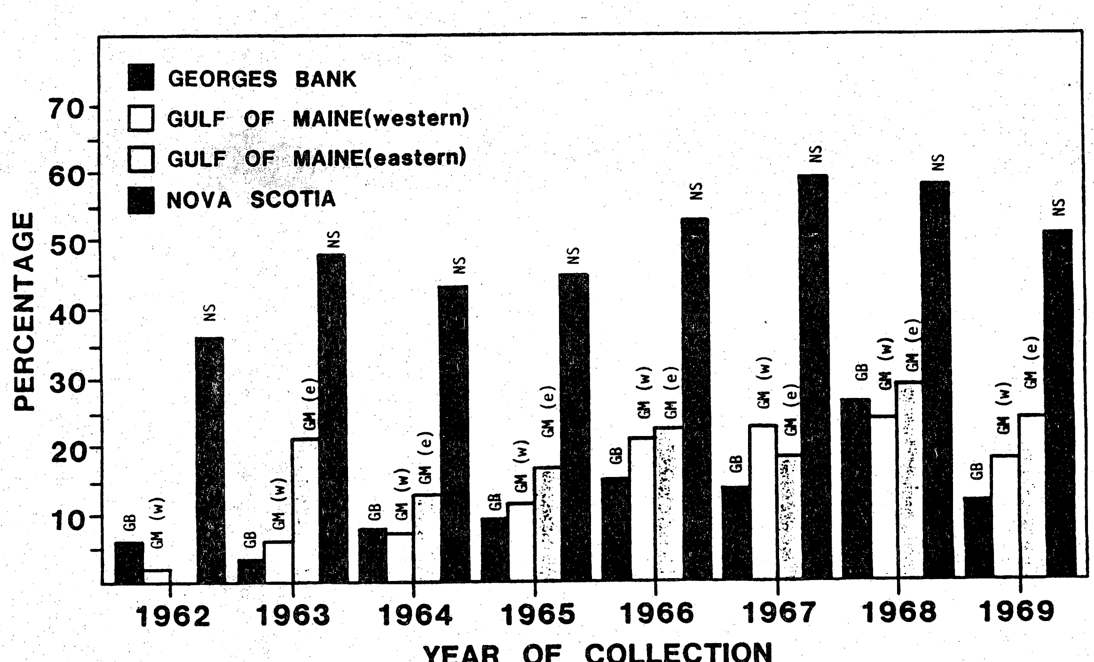

Figure 2. Annual prevalences of larval nematodes in principal herring stocks (from Boyar and Perkins, 1971).