Scientific Reports of the
Hokkaido Salmon Hatchery
No. 46: 175-203, March 1992

北海道さけ・ますふ化場
研究報告 第46号 175-203頁
1992年3月

Host Range and Geographical Distribution of the Ectoparasitic Protozoans *Ichthyobodo necator*, *Trichodina truttae* and *Chilodonella piscicola* on Hatchery-Reared Salmonids

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Abstract

The occurrence of *Ichthyobodo necator*, *Trichodina truttae* and *Chilodonella piscicola* was investigated on juvenile Pacific salmon (chum, pink, masu and sockeye salmon) reared at 204 hatcheries in northern Japan. These ectoparasitic protozoans were widespread in the area at water temperatures between 2° and 15°C. *Ichthyobodo necator* was most common among them, being recorded from all four salmonid species. *Chilodonella piscicola* was found on the former three fish species, and *T. truttae* was encountered on only chum salmon. The percentage of positive hatcheries was 37.3% for *I. necator*, 15.2% for *T. truttae*, and 8.8% for *C. piscicola*. The occurrence of *Ichthyobodo* infections was not related to type of water supply (spring, well, infiltrate, or river waters), which implies that there are other mechanisms to spread the parasite among host populations besides direct transmission. In contrast, the majority of *Trichodina* and *Chilodonella* infections occurred at the hatcheries supplied with river water, suggesting that wild fish may serve as the reservoirs of infection. Statistical comparisons indicated the existence of a possible interference competition between *I. necator* and *T. truttae* on the host body surface.

Introduction

Salmon enhancement has developed very rapidly for decades in the North Pacific rim nations (USA, Canada, Japan and Russia) to supplement natural production. This intensive artificial culture increases the risk of disease outbreaks in hatcheries.

More than 175 species of parasites have been recorded from Pacific salmon (*Oncorhynchus*) within their native range, but the principal parasitic diseases of hatchery-reared salmonids are caused by protozoans (Margolis, 1982). At least 15 protozoan species have been implicated in mortalities of cultured salmon (Margolis, 1982). Ectoparasitic protozoans often bring about severe problems in intensive culture because they can rapidly multiply and be directly transmitted in such conditions. They include the flagellate *Ichthyobodo necator* (Henneguy, 1883), and the ciliates *Trichodina truttae*

Contribution A No. 335 from the Hokkaido Salmon Hatchery
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Mueller, 1937 and *Chilodonella piscicola* (Zacharias, 1894).

The bodonid *I. necator* is widely distributed in the northern hemisphere and infects various freshwater fishes as well as marine salmonids (Robertson, 1985; Urawa and Kusakari, 1990). Heavy infections cause severe epidermal destruction in the skin and gills of salmonids (Robertson et al., 1981; Urawa, 1992a) and markedly reduce the adaptability of anadromous hosts to marine environment due to osmoregulatory breakdown (Urawa, 1992b). Despite this, the parasite infections are often overlooked because of their small size and the lack of obvious symptoms in infected fish.

The large ciliate *T. truttae* has been found on salmonids reared at hatcheries along the coasts of the North Pacific Ocean and adjacent seas (Davis, 1947, 1953; Bogdanova, 1963, 1967, 1977; Arthur and Margolis, 1984; Urawa and Arthur, 1991). Mortalities associated with heavy infections were recorded in hatchery-reared juveniles (Bogdanova and Shtein, 1963; Takeda et al., 1969; Takeda, 1971; Hoskins et al., 1976). An infection experiment (Urawa, 1992c) confirmed that the parasite is site-specific to host's skin and causes intense irritation and mortalities.

Chilodonella piscicola (= *C. cyprini*) is commonly found on the gills and skin of various freshwater fishes in North America, Europe and Asia (Hoffman, 1978). The parasite causes severe proliferation of the gill epithelium, which is followed by chronic mortalities of host salmonids (Urawa and Yamao, 1992).

Thus, these ectoparasitic protozoans are important pathogens of hatchery-reared salmonids, responsible for mass mortalities and large economic losses. Their epizootiology has, however, received relatively little attention. The present study describes the host range and geographical distribution of the ectoparasites infecting hatchery-reared salmonids in northern Japan, and discusses their dispersal mechanisms among host populations.

Materials and Methods

Fish were sampled from 204 freshwater hatcheries in six prefectures of northern Japan during the period of March 1982 - May 1991 (Appendices 1 & 2). A total of 9,449 fish were collected, comprising 8,660 chum (*Oncorhynchus keta*), 391 pink (*O. gorbuscha*), 65 sockeye (*O. nerka*, including kokanees) and 333 masu (*O. masou*) salmon (Table 1). The majority of these samples were underyearling juveniles within 3 months of the first feeding. The fish were immediately fixed in 10% formalin at the hatcheries and preserved for later parasitological examination in the laboratory (Hokkaido Salmon Hatchery). Additional investigations were made to determine the type of water supply and water temperatures in rearing ponds. The classification of water supply was in accordance with the concept defined by Shimizu (1984). *Ichthyobodo necator* is most abundant on the fins (Urawa, 1992a), and *C. piscicola* is usually defined to the gills (Urawa and Yamao, 1992). After measurements of fish size (folk length and wet weight), the dorsal and anal fins and gills were removed from fish and examined for parasites with a light microscope at magnifications of × 200-400. In addition, sediment in the bottom of the sample bottles was examined for *T. truttae* and *C. piscicola* because

Table 1. The occurrence of ectoparasitic protozoans on 4 species of salmonids reared at hatcheries in Hokkaido and northern Honshu.

Host species	No. of hatcheries studied	No. of positive hatcheries*1			Total no. of fish examined
		Ichthyobodo necator	*Trichodina truttae*	*Chilodonella piscicola*	
Hokkaido					
Chum salmon	118	41 (34.7)	19 (16.1)	6 (5.1)	5209
Pink salmon	17	3 (17.6)	0 (0)	1 (5.9)	391
Masu salmon	12	9 (75.0)	0 (0)	5 (41.7)	333
Sockeye salmon*2	3	1 (33.3)	0 (0)	0 (0)	65
Honshu					
Chum salmon	75	30 (40.0)	12 (16.0)	7 (9.3)	3451

*1Number of hatcheries where each parasite was recorded (proportion of positive hatcheries in %).
*2Sockeye salmon includes kokanees.

Table 2. The occurrence of ectoparasitic protozoans on juvenile salmonids at hatcheries in different coastal regions of Hokkaido and northern Honshu.

Region	No. of hatcheries studied	No. of positive hatcheries*		
		Ichthyobodo necator	*Trichodina truttae*	*Chilodonella piscicola*
Hokkaido				
1. Nemuro Strait	21	7 (33.3)	7 (33.3)	3 (14.3)
2. Sea of Okhotsk	27	8 (29.6)	2 (7.4)	1 (3.7)
3. Sea of Japan	29	8 (27.6)	7 (24.1)	5 (17.2)
4. Tsugaru Strait	7	1 (14.3)	0 (0)	0 (0)
5. Pacific Ocean(west)	21	12 (57.1)	1 (4.8)	0 (0)
6. Pacific Ocean(east)	24	10 (41.7)	2 (8.3)	2 (8.3)
Subtotal	129	46 (35.7)	19 (14.7)	11 (8.5)
Honshu				
7. Tsugaru Strait	11	7 (63.6)	2 (18.2)	2 (18.2)
8. Pacific Ocean	37	10 (27.0)	5 (13.5)	2 (5.4)
9. Sea of Japan	27	13 (48.1)	5 (18.5)	3 (11.1)
Subtotal	75	30 (40.0)	12 (16.0)	7 (9.3)
Total	204	76 (37.3)	31 (15.2)	18 (8.8)

*Number of hatcheries where each parasite was recorded (proportion of positive hatcheries in %).

these ciliates are easily detached from their hosts in formalin. Parasitological terms follow the definitions given by Margolis et al. (1982).

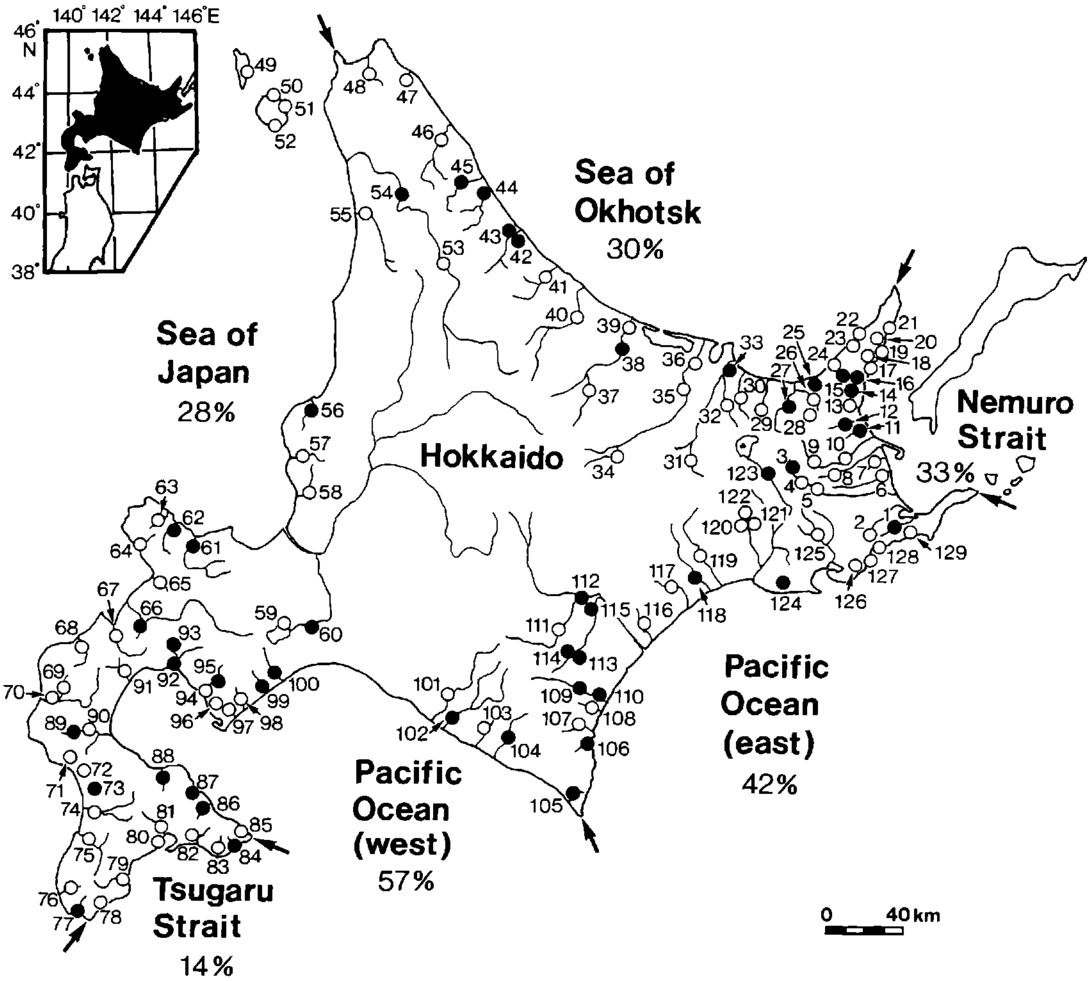

Fig. 1. The geographical distribution of *Ichthyobodo necator* at salmon hatcheries in Hokkaido. Solid circles indicate the locations of positive hatcheries where the parasite was recorded and open circles indicate the locations of negative hatcheries. Numerals refer to hatcheries listed in Appendix 1. Large arrows indicate the boundaries between regions. Percentages express the proportion of positive hatcheries in each coastal region.

Results

Ichthyobodo necator

Host range. This parasite was recorded from all four species, chum, pink, masu and sockeye salmon, but there was a slight difference in its occurrence among the host species (Table 1). The prevalence of infection averaged 43.0% in masu, 27.0% in sockeye, 24.3% in chum, and only 1.7% in pink salmon (Appendices 1 & 2).

Distribution. The parasite was quite widely distributed in northern Japan (Figs. 1 & 2). It was found at 46 hatcheries (36%) studied in Hokkaido, and at 30 hatcheries (37

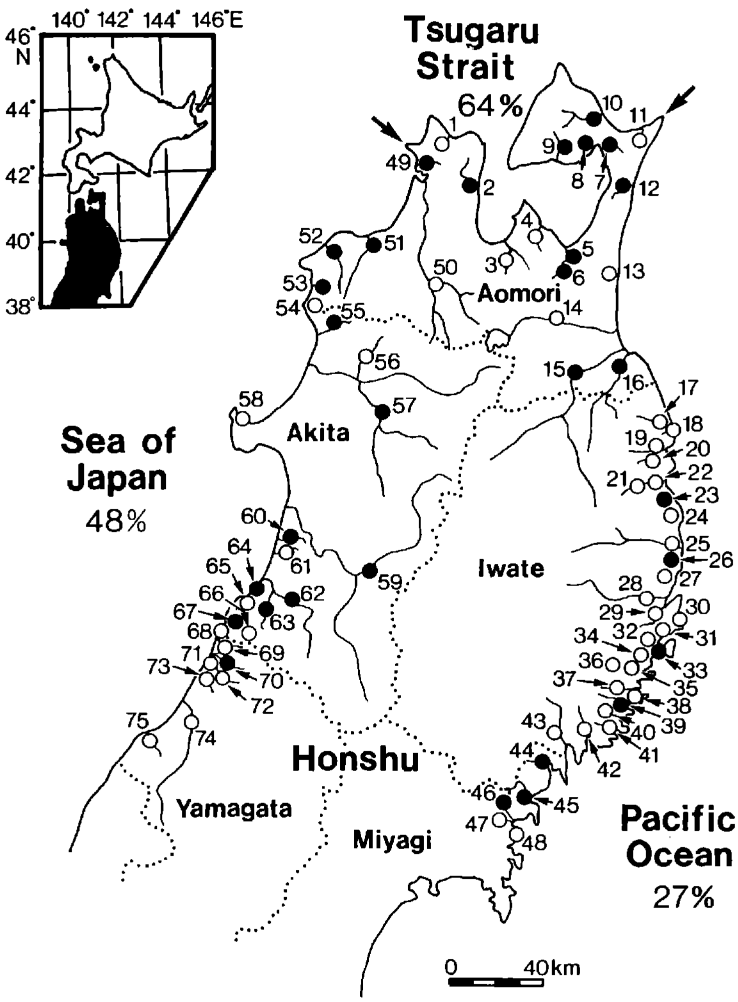

Fig. 2. The geographical distribution of *Ichthyobodo necator* at salmon hatcheries in northern Honshu. Solid and open circles indicate the locations of positive and negative hatcheries, respectively. Numerals refer to hatcheries listed in Appendix 2. Large arrows and dotted lines indicate the boundaries between regions and prefectures, respectively. Percentages express the proportion of positive hatcheries in each coastal region.

%) in northern Honshu (Table 2). The proportion of *Ichthyobodo*-positive hatcheries was relatively high (48–64%) along the Pacific coasts of Hokkaido (regions 5 & 6) and the Japan Sea coasts of Honshu (regions 7 & 9). In particular, the infection was most prevalent along the coasts of inlets such as Volcano Bay (Uchiura wan) in the Pacific west region of Hokkaido and Mutsu Bay in Aomori Prefecture, where the proportion of positive hatcheries was 66.7% and 75.0%, respectively. Annual surveys confirmed that infections occurred every year at several hatcheries (e.g., Chitose, Yoichi and Hiroo hatcheries; Appendixes 1 & 2).

Environment. The parasite infections broke out in hatcheries with all the types of

Table 3. The frequency (%) of ectoparasitic protozoans on hatchery-reared juvenile salmonids in northern Japan with different types of water supply.

Type of water supply	Frequency* (%)			Water temperature (℃)	
	Ichthyobodo necator	*Trichodina truttae*	*Chilodonella piscicola*	Mean	Range
Spring water (S)	18.2 (10/55*)	3.6 (2/55)	3.6 (2/55)	8.0	5.0-10.4
Well water (W)	24.4 (20/82)	1.2 (1/82)	6.1 (5/82)	8.1	2.0-13.6
S + W	25.0 (2/ 8)	25.0 (2/ 8)	0 (0/ 8)	7.8	7.0- 9.0
Infiltrate water (I)	28.6 (6/21)	9.5 (2/21)	0 (0/21)	8.5	6.0-10.4
W + I	57.1 (4/ 7)	14.3 (1/ 7)	14.3 (1/ 7)	9.6	8.4-11.7
S + I	100.0 (1/ 1)	0 (0/ 1)	0 (0/ 1)	5.5	-
River water (R)	25.0 (11/44)	20.5 (9/44)	2.3 (1/44)	7.3	3.0-15.0
S + R	45.6 (26/57)	21.1 (12/57)	12.3 (7/57)	5.8	3.5-10.5
W + R	53.4 (39/73)	15.1 (11/73)	16.4 (12/73)	6.9	2.6-13.0
S + W + R	71.4 (5/ 7)	0 (0/ 7)	14.3 (1/ 7)	6.4	6.0- 7.2
F + R	44.4 (4/ 9)	11.1 (1/ 9)	0 (0/ 9)	9.8	6.0-12.4
S + Lake water	100.0 (1/ 1)	0 (0/ 1)	0 (0/ 1)	1.8	-

*Number of groups in which each parasite was recorded/total number of sample groups examined.

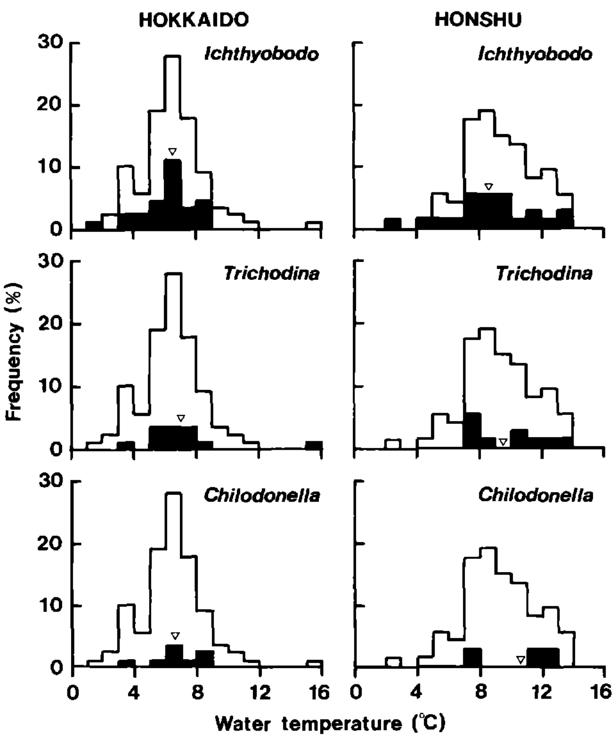

Fig. 3. The frequency histograms showing the occurrence of *Ichthyobodo necator*, *Trichodina truttae*, and *Chilodonella piscicola* on hatchery-reared salmonids in Hokkaido and northern Honshu at different water temperatures. Total number of sample groups is 90 in Hokkaido and 74 in Honshu. Solids and opens indicate the percentage of infected and uninfected sample groups, respectively. Arrowheads represent the mean water temperature at which the parasite was observed.

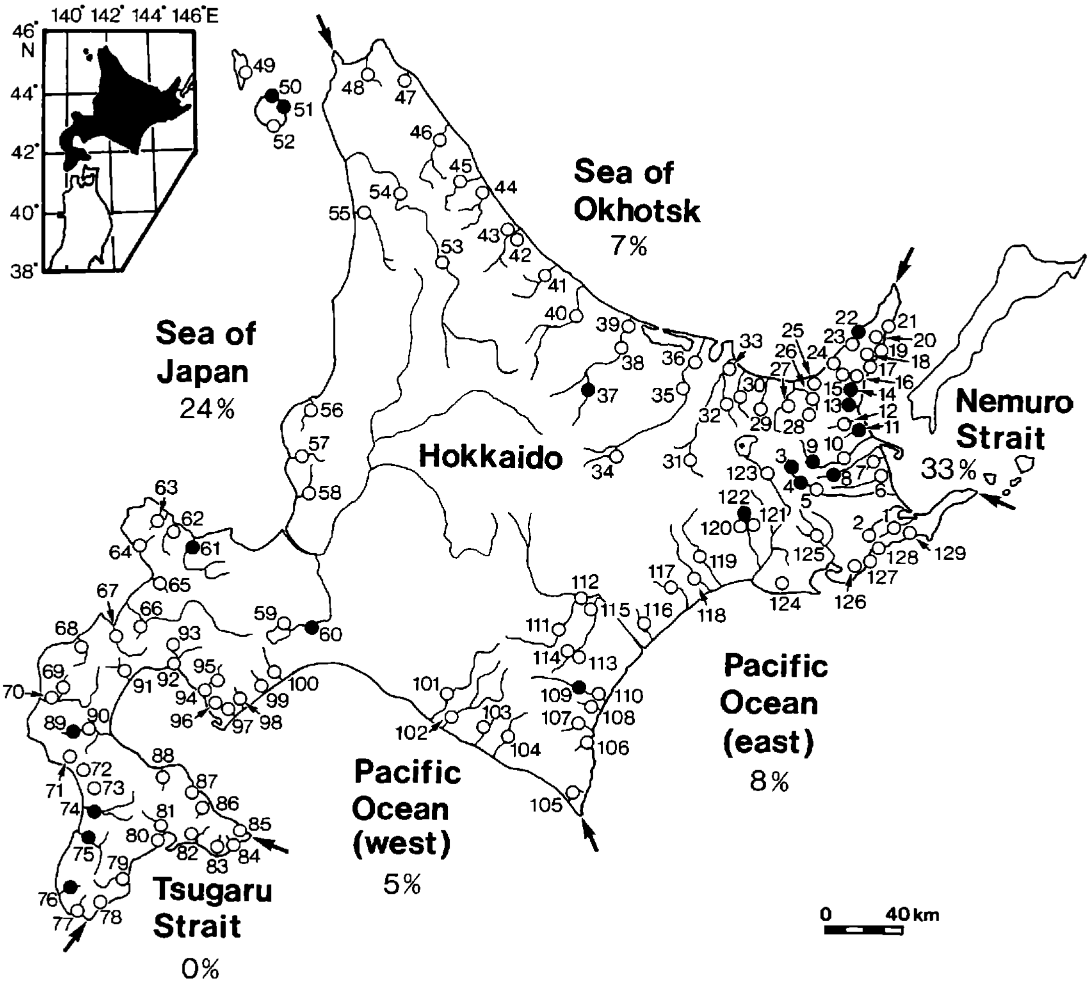

Fig. 4. The geographical distribution of *Trichodina truttae* at salmon hatcheries in Hokkaido. Solid and open circles indicate the locations of positive and negative hatcheries, respectively. Numerals refer to hatcheries listed in Appendix 1. Large arrows indicate the boundaries between regions. Percentages express the proportion of positive hatcheries in each coastal region.

water supply (Table 3). The frequency of infections (number of parasite-positive groups/total number of sample groups) was approximately the same (18.2-28.6%) among individual type of water supply (spring, well, infiltrate, or river waters), but increased to 45.6-71.4% when river water was mixed with other types of water supply. Infections were found at a wide range of water temperatures (1.8°-13.6°C) (Fig. 3). The mean water temperature recorded when infections were observed was 6.1°C in Hokkaido and 8.7°C in Honshu.

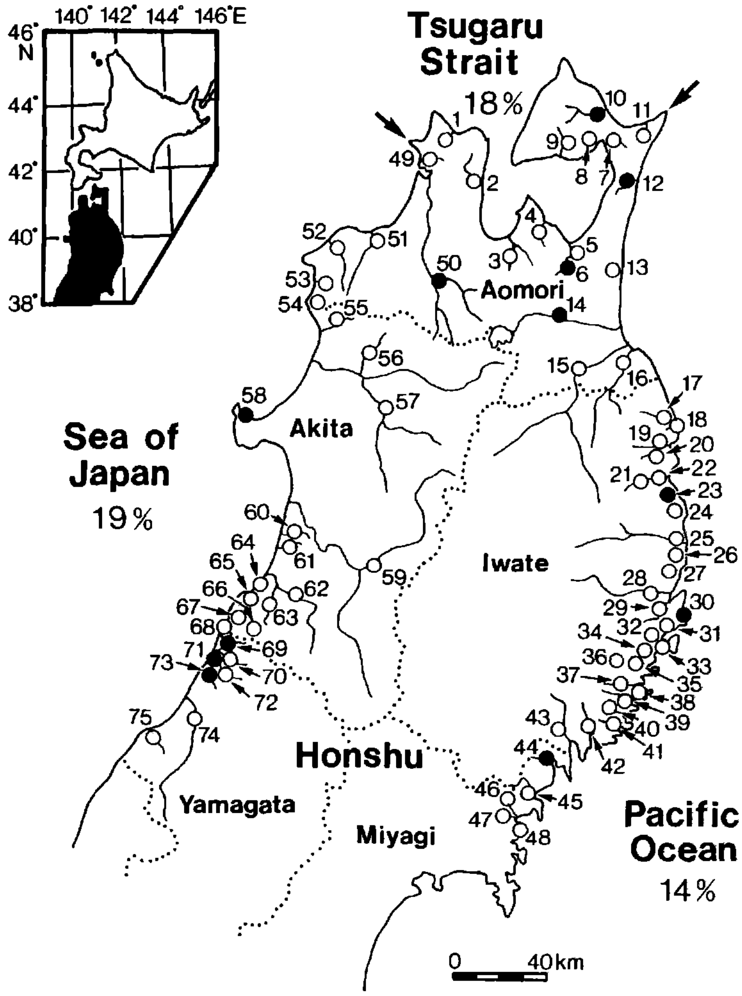

Fig. 5. The geographical distribution of *Trichodina truttae* at salmon hatcheries in northern Honshu. Solid and open circles indicate the locations of positive and negative hatcheries, respectively. Numerals refer to hatcheries listed in Appendix 2. Large arrows and dotted lines indicate the boundaries between regions and prefectures, respectively. Percentages express the proportion of positive hatcheries in each coastal region.

Trichodina truttae

Host range. This ciliate was recorded only from chum salmon (Table 1).

Distribution. The parasite was found at 14.7% of the hatcheries in Hokkaido and 15.2% of those in northern Honshu (Table 2, Figs. 4 & 5). The proportion of *Trichodina*-positive hatcheries was almost uniform (13.5-18.5%) throughout the regions of northern Honshu, but varied considerably from region to region in Hokkaido, where it was high in hatcheries along the shores of Nemuro Strait (region 1, 33.3%) and the Sea of Japan (region 3, 27.6%) but low (0-8.3%) in those along other coastal regions.

Environment. The distribution of *T. truttae* varied significantly with the type of

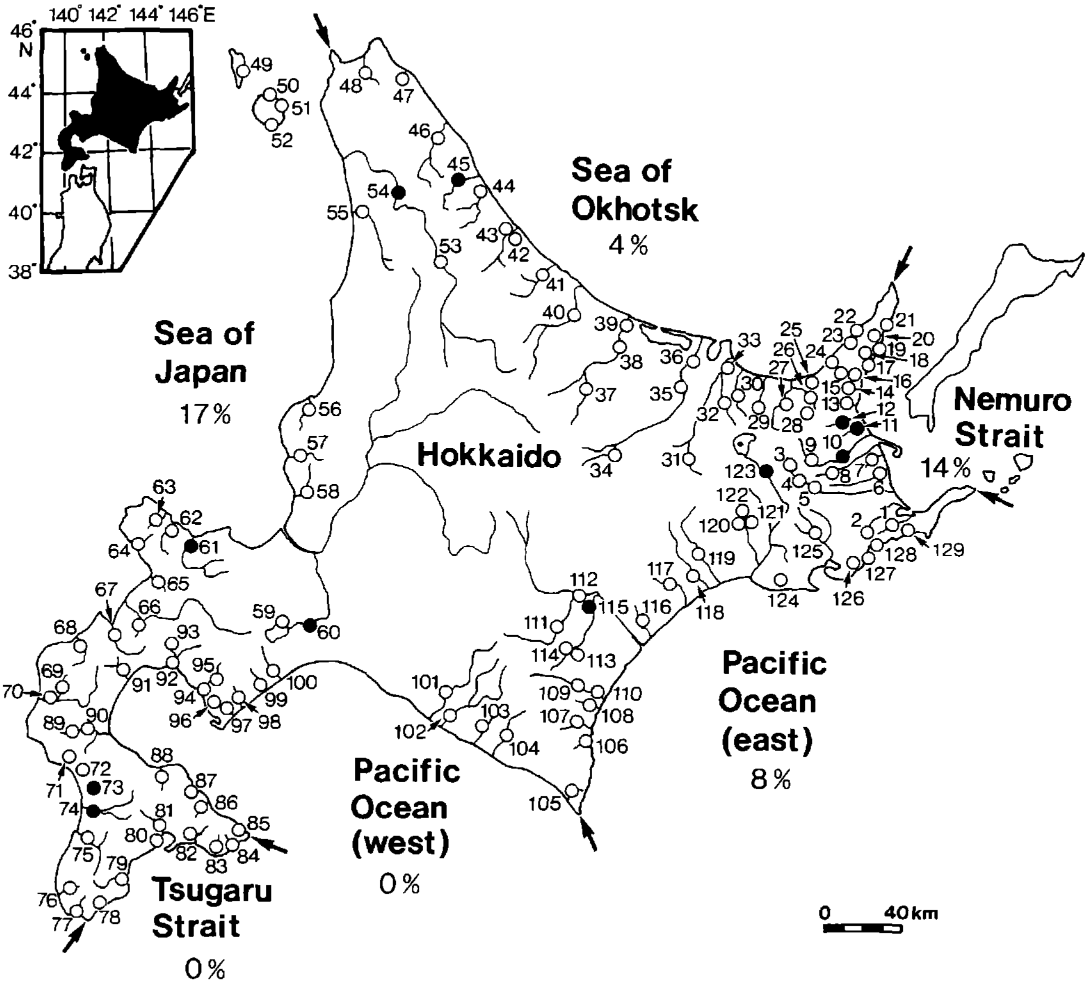

Fig. 6. The geographical distribution of *Chilodonella piscicola* at salmon hatcheries in Hokkaido. Solid and open circles indicate the locations of positive and negative hatcheries, respectively. Numerals refer to hatcheries listed in Appendix 1. Large arrows indicate the boundaries between regions. Percentages express the proportion of positive hatcheries in each coastal region.

water supply (Table 3). More than 80% of infections were observed in hatcheries where river water, solely or with other waters, was used. The water temperatures in which the parasite was found were between 3.0°C and 15.0°C, averaging 7.0°C in Hokkaido and 9.8°C in Honshu (Fig. 3).

Chilodonella piscicola

Host range. This ciliate parasite was recorded from chum, pink and masu salmon (Table 1). The proportion of *Chilodonella*-positive hatcheries was highest (41.7%) for masu salmon, as compared to only 5.1% and 5.9% for chum and pink salmon, respec-

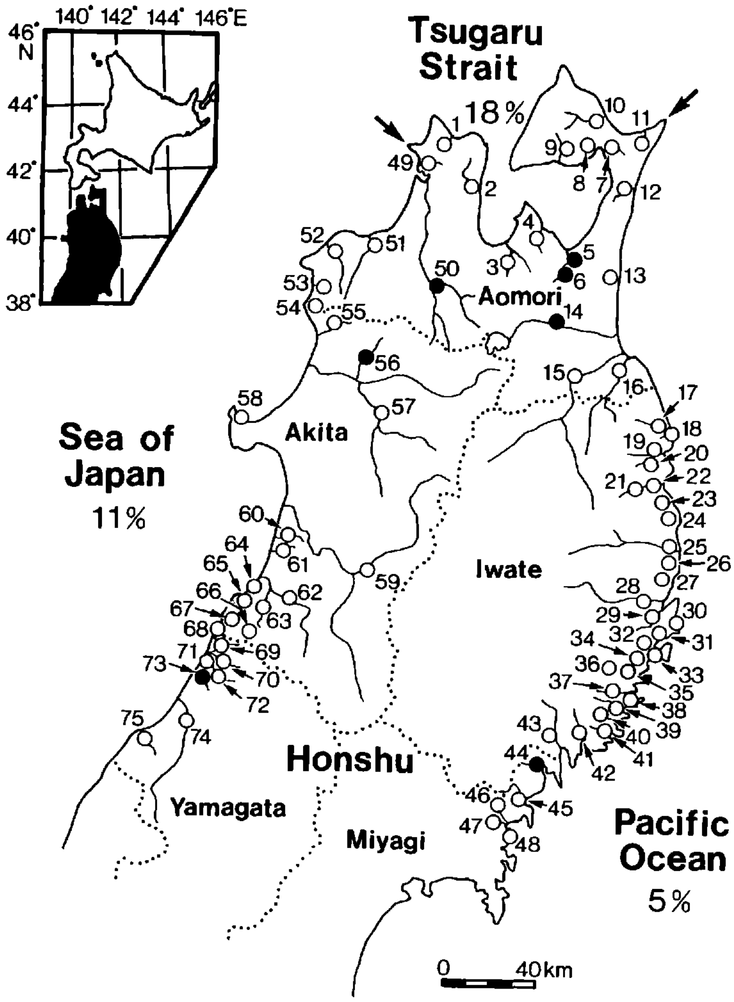

Fig. 7. The geographical distribution of *Chilodonella piscicola* at salmon hatcheries in northern Honshu. Solid and open circles indicate the locations of positive and negative hatcheries, respectively. Numerals refer to hatcheries listed in Appendix 2. Large arrows and dotted lines indicate the boundaries between regions and prefectures, respectively. Percentages express the proportion of positive hatcheries in each coastal region.

tively. Most infections of masu salmon occurred during their first feeding period.

Distribution. This parasite was the least common of the three species of ectoparasites, being found in only 8.8% of the hatcheries surveyed in Hokkaido and Honshu (Table 2, Figs. 6 & 7). There were no apparent regional differences in the proportion of *Chilodonella*-positive hatcheries except for the Hokkaido coasts of Tsugaru Strait (region 4) and Pacific Ocean (region 5), where the ciliate was not recorded.

Environment. The occurrence of outbreaks was highest (14.6%) under rearing conditions where river water was mixed with spring and/or well water, as compared to the other types of water supply (Table 3). The parasite was recorded at water tempera-

Table 4. The observed and expected coexistence among *Ichthyobodo necator*, *Trichodina truttae*, and *Chilodonella piscicola* on juvenile chum salmon reared at hatcheries using river water. The table includes three cases of concurrent infections with three species.

Parasites		No. of infections*1			Total no. of infections
		Ichthyobodo	*Trichodina*	*Chilodonella*	
Ichthyobodo	Observed	58 (72.5*2)	12 (15.0)	10 (12.5)	80 (100.0)
necator	Expected	48 (60.0)	21 (26.3)	11 (13.7)	80 (100.0)
Trichodina	Observed	12 (33.3)	17 (47.2)	7 (19.5)	36 (100.0)
truttae	Expected	21 (58.3)	10 (27.8)	5 (13.9)	36 (100.0)
Chilodonella	Observed	10 (52.6)	7 (36.9)	2 (10.5)	19 (100.0)
piscicola	Expected	11 (57.9)	5 (26.3)	3 (15.8)	19 (100.0)

*1 Expected coexistence is calculated by the hypothesis that each parasite's probability of infection is essentially random, being not affected by the presence of other parasite species. The number of expected cases of coexistence of parasite A with B ($EC_{A,B}$) is given by the formula: $EC_{A,B} = (ON_B/N) \times ON_A$, where ON_A = total number of observed infections of parasite A, ON_B = total number of observed infections of parasite B, N = total number of observed infections of parasites ($ON_A + ON_B + \ldots$).
*2 Proportion (%) of infections.

tures ranging from 3.0°C to 12.3°C, with an average of 6.5°C and 10.5°C in Hokkaido and Honshu, respectively (Fig. 3).

Interspecific competition

Table 4 compares the observed and expected frequency of coexistence among the parasite species on chum salmon reared at hatcheries with river water. Distinct differences between predicted and observed frequencies exist for the co-occurrence of *I. necator* and *T. truttae* but not in other cases (*C. piscicola* vs *I. necator* or *T. truttae*). The number of observed infections of *I. necator* concurrent with *T. truttae* was 43% lower than expected.

Other ectoparasites

A monogenean *Gyrodactylus masu* Ogawa, 1986 was occasionally found on the fins of juvenile chum, sockeye and masu salmon at Chitose Hatchery. In addition, unidentified sessile peritrichs (Peritrichida) attached to the fins of chum salmon fry reared at Asahi Hatchery on Rishiri Island, northern Hokkaido, but the prevalence of infections was low (8.7%).

Discussion

The ectoparasite fauna of hatchery-reared salmon juveniles examined here was predominantly composed of three protozoan species, *I. necator, T. truttae,* and *C. piscicola.* This simple fauna may be closely related to the short rearing period of the fish: the majority of juvenile chum and pink salmon are released after 2-3 months of feeding. It also seems to be limited by rearing water temperatures below 15°C. For example, the large ciliate *Ichthyophthirius multifiliis* occasionally causes considerable problems at trout and salmon farms in North America (Wood, 1979) and Europe (Bauer, 1959), but in northern Japan this ciliate was not observed perhaps due to the cold rearing water, whose temperature is considerably below the parasite's optimum (24° to 26°C, according to Bauer, 1959).

The three protozoan species were widely recorded in northern Japan at water temperatures ranging from 2° to 15°C. Although there were distinct differences in rearing temperatures between Hokkaido and Honshu, the frequency of infections with each parasite species was similar in both areas. Bauer (1959) mentioned that *C. piscicola* divides most actively at 5° to 10°C. This is almost consistent with the temperature range for *Chilodonella* infections observed in the present survey. On the other hand, Becker (1977) noted that *Ichthyobodo* survives at temperatures from 2° to 29°C and multiplies most rapidly at about 24°-25°C. At salmon hatcheries, however, infections were frequently encountered at temperatures between 1.8° and 13.6°C, suggesting that *I. necator* on salmonids is well adapted to lower temperatures.

Ichthyobodo necator and *C. piscicola* were recorded from four and three fish species, respectively. These two parasites are known to have a wide host range (Hoffman, 1978; Robertson, 1985). There was, however, a slight difference in the frequency of their occurrence among the salmonid hosts. These parasites were found most frequently on the first-feeding masu salmon, but rarely on juvenile pink salmon. In addition, *T. truttae* was found only on chum salmon. These results suggest that host susceptibility to each species of parasite may differ among salmonid species.

It is well recognized that *I. necator* is a common pathogen in trout and salmon farms in North America and Europe (Wood, 1979; Robertson, 1985), whereas this small flagellate has been overlooked in Japanese salmon hatcheries until quite recently*. The present intensive survey shows that *I. necator* is the most epizootic ectoparasite on hatchery-reared salmonids in Japan. The transmission of the parasite by transport of infected live fish was confirmed at one hatchery, however this probably does not account for the wide distribution of this parasite since live fish are rarely transported between hatcheries in the study area. The parasite is able to survive and multiply in seawater (Urawa and Kusakari, 1990). The expansion of parasite's distribution may be promoted by this seawater adaptability, while it seems to be also encouraged by other spread mechanisms.

It is generally considered that ectoparasitic protozoans usually transmit themselves directly from host to host. This implies that the occurrence of parasites may be influenced by the type of water supply (spring, well, infiltrate, or river waters). In the case of *T. truttae*, the majority of infections occurred in the ponds supplied with river water. A separate observation confirmed that wild salmonids were infected with *T. truttae* (Urawa, unpublished data). These findings indicate that wild fish serve as the main source of *Trichodina* infections in hatcheries. A similar trend was also observed in *C.*

*Urawa, S. (1984): The pathogenicity of *Ichthyobodo necator* on chum salmon fry. *In* Abstracts of the 1984 Annual Meeting of the Japanese Society of Fish Pathology. p. 5. (In Japanese.)

piscicola infections. Both ciliates occurred frequently along the coast of Nemuro Strait where about 80% of hatcheries used river water, but were rarely found in Iwate Prefecture where only 11% of hatcheries used river water. Thus, the distribution of these ciliates in hatcheries is strongly affected by type of water supply.

On the other hand, the frequency of *Ichthyobodo* infections was most stable among individual types of water supply and increased when mixed waters were used. This increase seems to just reflect the sum of risks in each types of water supply. Infections often occurred in isolated ponds supplied with spring or well water, in which wild fish were absent. Thus, besides the direct transmission, there may be any other mechanisms by which *Ichthyobodo* spreads among host populations. Some workers believe that the flagellate forms cysts in unfavorable conditions which remain in the water as well as on the host's body, although this has not been confirmed experimentally (see Bauer, 1959).

Both of *I. necator* and *T. truttae* are site-specific to the body surface of their hosts (Urawa, 1992a, 1992c). The observed coexistence of *I. necator* with *T. truttae* was significantly lower than expected, suggesting the presence of interference competition between these parasites. This assumption was corroborated by the experimental observation that *T. truttae* reduced the density of *I. necator* on the host skin (Urawa, unpublished data).

Trichodina truttae and *C. piscicola* infections may be controlled by using only spring or well waters in which feral fish are absent, whereas this method does not appear effective for the prevention of *I. necator*. Heavy *Ichthyobodo* infections reduce markedly the seawater adaptation of anadromous hosts and consequently cause high marine mortalities (Urawa, 1992b). It was confirmed that formalin bath treatment of infected chum juveniles significantly increased their return rate as adults (Urawa, unpublished data). Thus, it is strongly recommended that anadromous salmonids should be examined for parasites before their release from hatcheries.

Acknowledgments

I am very grateful to the staffs of the various salmon hatcheries for their assistance with the collection of fish samples. My sincere gratitude is extended to Mr. Yoshitaka Yoshida of Aomori Prefectural Fish Culture Center, Mr. Minoru Ube of Iwate Prefectural Southern Sea Farming Center, Mr. Akira Kumagai of Kesennuma Miyagi Prefectural Fisheries Experimental Station, Mr. Hiroshi Konaka of Akita Prefectural Freshwater Fisheries Experimental Station, and Mr. Yutaka Kasahara of Yamagata Prefectural Sakata Fisheries Office, for providing samples in Honshu. Dr. Kiyokuni Muroga of Hiroshima University, Dr. J. Richard Arthur of Maurice Lamontagne Institute, Canadian Fisheries and Oceans, and Mr. Hideki Nogawa of Hokkaido Salmon Hatchery gave helpful comments on an early draft of the manuscript.

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ふ化場産サケ科魚類に外部寄生する原生動物３種の宿主範囲と地理的分布

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外部寄生性原生動物３種（鞭毛虫 *Ichthyobodo necator*，繊毛虫 *Trichodina truttae* および *Chilodonella piscicola*）のサケ属魚類４種（サケ，カラフトマス，サクラマス，ベニザケ）における発生状況を北日本のふ化場２０４カ所で調査した．これら３種の外部寄生虫は北日本各地に広く分布し，水温2-15℃の範囲で観察された．*I. necator* はこれらの中で最も頻繁にみられ，サケ属４種から記録された．*C. piscicola* の宿主はサケ，カラフトマス，サクラマスの３種であったが，*T. truttae* はサケのみから記録された．寄生虫の観察されたふ化場の割合は，*I. necator* で37.3%，*T. truttae* で15.2%，*C. piscicola* では8.8%であった．*I. necator* の発生率と飼育用水の種類（湧水，地下水，浸透水あるいは河川水）の間には明確な関係がみられず，直接感染以外に宿主集団間に本虫が伝播する機構の存在することが暗示された．一方，*T. truttae* と *C. piscicola* の場合は，大部分が河川水を用いたふ化場で発生したことから，野生魚が主な感染源になっていると推定された．*I. necator* と *T. truttae* は宿主体表上で競合関係にあることが統計的分析によって示唆された．

EXPLANATION OF APPENDICES

1. *Region and hatchery.* – Hatcheries are mapped by number in Figs. 1, 2, 4-7.
2. *Fish species.* – Alevins are shown by "A" in parentheses followed by the fish name.
3. *No. of fish examined.* – Asterisks indicate that fish were treated with formalin before the parasitological examination.
4. *Mean length and weight.* – ND means data not available.
5. *Parasites.* – Numerals show the prevalence (%) of *Ichthyobodo necator* infections. The absence or presence of the ciliate parasites was expressed by "+" or "–", respectively.
6. *Type of water supply.* – S, spring water; W, well water; I, infiltrate water; R, river water; L, lake water.
7. *Temperature of water supply.* – The water temperature (°C) in the rearing pond where fish were sampled was indicated in parentheses.

Appendix 1. The occurrence of *Ichthyobodo necator* (ICH), *Trichodina truttae* (TRI) and *Chilodonella piscicola* (CHI) on hatchery-reared juvenile salmonids in Hokkaido.

No.	Region / Hatchery	Fish species	Collection date	No. fish examined	Mean length (cm)	Mean Weight (g)	Parasites ICH	TRI	CHI	Water supply Type (Temp.)
I.	**Nemuro Strait**									
1	Bettoga	Chum	MAY-25-89	30	4.9	1.18	63	-	-	R
		Masu	MAR-10-89	20	2.8	0.23	100	-	-	R
		Pink	MAY-10-89	61	3.3	0.24	0	-	-	R
2	Hamanaka	Chum	APR-29-89	40*	4.2	0.73	0	-	-	W+R (6.0)
3	Nizibetsu	Chum	MAR-26-82	8	3.5	0.30	25	+	-	S
		Chum	MAR-15-89	10	4.1	0.64	0	+	-	S (8.5)
		Sockeye	MAR-15-89	30	2.5	0.12	0	-	-	S (9.0)
4	Nishibetsu	Chum(A)	MAR-15-89	10*	3.3	0.33	0	+	-	R (4-10)
		Chum	MAY-11-89	30*	6.2	2.59	0	+	-	R (15.0)
5	Honbetsu	Pink	MAR-13-91	30	3.5	0.37	0	-	-	S (7.0)
6	Tokotan	Chum	MAR-20-89	40*	3.5	0.38	0	-	-	S+R
		Chum	APR-11-89	30*	4.0	0.69	0	-	-	S+R
		Chum	MAR-14-91	30	4.0	0.62	0	-	-	S+R (4.0)
7	Shunbetsu	Pink	APR-21-89	30	3.2	0.18	0	-	-	S (5.0)
8	Kenebetsu	Chum	MAR-23-82	7	3.5	0.40	0	-	-	R
		Chum	MAR-15-89	10	3.7	0.48	0	-	-	R (6.0)
		Chum	APR-18-89	51	4.5	1.03	0	+	-	R (7.0)
9	Nakashibetsu	Chum	APR-21-89	60	4.5	0.98	0	+	-	S+R (6.5)
10	Nemuro	Pink	MAY-21-87	50	4.0	0.60	0	-	-	S+R
		Pink	MAY-16-88	10	4.2	0.42	0	-	+	S+R
		Masu	MAY-21-87	50	4.1	0.91	0	-	-	S+R
		Masu	APR-07-88	10	4.6	0.83	0	-	+	S+R
		Masu	MAR-04-91	10	3.1	ND	0	-	+	S+R
11	Ichani	Chum	MAR-25-82	7	3.3	0.30	57	+	-	W+R
		Chum	MAR-16-89	30*	3.9	0.52	0	+	-	W+R (5.0)
		Masu	MAY-22-87	10*	3.6	0.29	0	-	+	W
12	Tyurui	Chum	FEB-06-82	10	3.8	0.35	100	-	-	S+W+R
		Chum	FEB-20-82	10	3.8	0.37	70	-	-	S+W+R
		Chum	MAR-02-82	5	4.0	0.42	100	-	+	S+W+R
		Chum	MAR-25-82	5*	4.1	0.69	0	-	-	S+W+R
13	Kunbetsu	Chum	MAR-16-82	10	ND	ND	0	-	-	S+R
		Chum	APR-07-88	60	3.4	0.35	0	+	-	S+R
14	Motosakimui	Chum	MAR-30-88	10	4.1	0.68	10	+	-	S+R
15	Mosekarubetsu	Chum	MAR-24-82	6	3.6	ND	50	-	-	S+R
		Chum	MAY-20-88	60	4.7	1.06	0	-	-	S+R

Appendix 1. (continued)

Region		Fish species	Collection date	No. fish examined	Mean length	Mean Weight	Parasites			Water supply
No.	Hatchery				(cm)	(g)	ICH	TRI	CHI	Type (Temp.)
16	Uebetsu	Chum	MAR-19-88	30	4.2	0.79	100	-	-	W+R
17	Rikushibetsu	Chum	JUN-10-88	60	5.2	1.37	0	-	-	S (7.1)
18	Rausu	Chum	MAR-25-82	4	3.6	0.41	0	-	-	R
		Chum	MAY-26-88	60	4.8	1.15	0	-	-	R
19	Yunosawa	Chum	MAY-18-88	60	5.1	1.33	0	-	-	R
20	Sashirui	Pink	APR-30-88	10	3.5	0.29	0	-	-	R
21	Rusa	Chum	MAY-30-88	60	4.9	1.24	0	-	-	S+W
II.	**Sea of Okhotsk coast**									
22	Iwaobetsu	Chum	APR-11-89	10	3.7	0.38	0	+	-	R
23	Hamaiwaobetsu	Pink	APR-11-89	10	3.3	0.31	0	-	-	R
24	Onnebetsu	Pink(A)	APR-11-89	10	3.2	0.29	0	-	-	R
25	Okushibetsu	Pink(A)	MAR-29-88	30	3.1	0.24	3	-	-	R (4.8)
		Pink	APR-11-89	10	3.3	0.28	0	-	-	R
26	Raiun	Chum	MAR-29-88	10	4.5	0.92	0	-	-	S
		Chum	APR-01-89	10	5.0	1.34	0	-	-	S
		Pink	APR-11-89	10	3.3	0.22	0	-	-	S
27	Shari	Chum	MAR-24-82	17	3.8	0.44	0	-	-	S
		Chum	MAR-16-89	10	4.0	0.58	0	-	-	S
		Chum	APR-12-89	10	4.5	0.90	0	-	-	S
		Pink	MAR-24-82	10	3.4	0.21	0	-	-	S
		Masu	MAY-12-84	5	4.2	0.64	0	-	-	S
		Masu	JAN-22-87	10	3.1	0.20	100	-	-	S
		Masu	JAN-27-87	10	2.8	0.13	100	-	-	S
		Masu	JAN-28-87	20*	3.0	0.15	0	-	-	S
		Masu	APR-12-89	10	3.2	0.35	20	-	-	S
28	Akinokawa	Chum	APR-11-89	10	4.1	0.69	0	-	-	S
29	Yanbetsu	Chum	MAR-29-88	10*	3.9	0.63	0	-	-	S+R
		Chum	APR-12-89	10*	3.9	0.58	0	-	-	S+R
30	Mokoto	Chum	APR-12-89	10	3.9	0.52	0	-	-	S
31	Aioi	Chum	APR-12-89	10	4.0	0.62	0	-	-	S+R
32	Kaminosato	Chum	APR-12-89	10	3.6	0.38	0	-	-	S
33	Abashiri	Chum(A)	MAR-29-88	20	3.3	0.31	100	-	-	S+L (1.8)
		Chum	APR-12-89	10	3.9	0.57	100	-	-	S+L
34	Oketo	Chum	MAR-30-88	10	3.6	0.46	0	-	-	S
		Chum	APR-07-89	10	3.6	0.36	0	-	-	S

Appendix I. (continued)

Region No.	Hatchery	Fish species	Collection date	No. fish examined	Mean length (cm)	Mean Weight (g)	Parasites ICH	TRI	CHI	Water supply Type (Temp.)
35	Kitami	Chum	MAR-16-89	20	3.5	0.40	0	-	-	W
36	Tokoro	Pink	APR-13-89	10*	3.3	0.26	0	-	-	S+R
37	Maruseppu	Chum	MAR-30-88	30	4.0	0.60	0	-	-	S+R
		Chum	APR-07-89	10	4.1	0.67	0	+	-	S+R
38	Yubetsu	Chum	APR-18-85	10	4.4	0.59	10	-	-	W
		Pink	APR-18-85	10	3.7	0.30	10	-	-	W
		Pink	APR-17-89	10*	4.6	0.98	0	-	-	W (9.0)
39	Yubetsugosen	Chum	MAR-30-88	20	4.3	0.77	0	-	-	W
		Chum	APR-07-89	10	4.6	0.97	0	-	-	W
40	Shokotsu	Chum	MAR-28-86	20	4.0	0.67	0	-	-	W (7.9)
		Chum	MAR-30-88	10	5.1	1.45	0	-	-	W
		Chum	APR-13-89	10	5.0	1.45	0	-	-	W (8.0)
41	Okoppe	Chum(A)	MAR-31-88	10	3.4	0.39	0	-	-	R
		Pink	APR-13-89	10*	3.2	0.28	0	-	-	R
42	Horonaiminami	Chum	MAR-31-88	10	4.3	0.76	40	-	-	W
43	Horonai	Chum	MAR-24-82	5	3.3	0.23	30	-	-	W
		Chum(A)	JAN-09-87	29	3.5	0.33	0	-	-	W
		Chum	MAR-31-88	10	4.3	0.84	100	-	-	W
		Chum	APR-13-89	10	5.9	2.20	100	-	-	W (5.5)
44	Tokushibetsu	Chum	MAR-23-82	11	3.9	0.52	9	-	-	W
		Chum	JAN-31-89	10	3.6	0.41	0	-	-	W (5.4)
		Chum	MAR-20-89	10	4.3	0.83	0	-	-	W (4.0)
		Masu	MAR-23-82	5	2.8	0.19	100	-	-	W
		Masu	JAN-31-89	10	2.9	0.23	0	-	-	W (5.4)
		Masu	MAR-20-89	10	3.4	0.40	0	-	-	W (4.0)
		Pink	MAR-23-82	10	3.2	0.21	20	-	-	W
45	Utanobori	Chum	MAR-27-86	20	4.1	0.76	0	-	-	W (2.0)
		Chum	APR-05-88	10	4.5	0.98	0	-	-	W (3.1)
		Chum	FEB-03-89	10	3.3	0.39	0	-	-	W (3.6)
		Pink	APR-05-88	10	3.6	0.38	0	-	-	W (3.1)
		Masu	MAY-31-88	10	3.6	0.53	100	-	+	W (6.5)
		Masu(A)	FEB-07-89	10	2.8	0.21	0	-	-	W (3.6)
46	Tonbetsu	Chum	MAR-27-86	19	4.6	0.94	0	-	-	W (6.5)
		Chum	MAY-07-88	10	4.2	0.79	0	-	-	W
47	Onishibetsu	Pink	MAR-31-88	50	3.2	0.22	0	-	-	S+R
48	Souya	Chum	APR-08-88	60	4.1	0.75	0	-	-	R

Appendix 1. (continued)

Region No.	Region Hatchery	Fish species	Collection date	No. fish examined	Mean length (cm)	Mean Weight (g)	Parasites ICH	Parasites TRI	Parasites CHI	Water supply Type (Temp.)
III.	**Sea of Japan**									
49	Kafukai	Pink	APR-17-90	10	3.0	0.23	0	-	-	R
50	Higashirishiri	Chum	MAY-08-88	61	4.5	0.91	0	+	-	R (5.8)
51	Asahi	Chum	MAR-26-86	6	3.6	0.30	0	+	-	R (5.4)
		Chum	MAY-08-88	23	4.5	0.93	0	-	-	R
52	Rishiri	Chum	APR-27-88	45	5.3	1.27	0	-	-	W
53	Teshio	Chum	FEB-21-82	10	3.7	0.35	0	-	-	W
		Chum	MAR-23-82	8	4.4	ND	0	-	-	W
		Chum	MAR-30-88	30	4.3	0.79	0	-	-	S+W
		Chum	FEB-06-89	10	3.3	0.29	0	-	-	S (9.5)
		Chum	MAR-29-89	60	4.7	0.93	0	-	-	W
54	Nakagawa	Chum	MAR-24-86	41	3.4	0.33	0	-	-	W (3.3)
		Chum	APR-20-87	35	3.8	0.49	74	-	-	W (3.5)
		Chum	MAR-20-88	10	4.9	1.17	0	-	-	
		Chum	JAN-30-89	10	3.4	0.34	0	-	-	W (6.6)
		Chum	APR-01-89	10	4.5	0.94	40	-	-	W (6.0)
		Masu	APR-10-89	10	3.5	0.37	100	-	+	W (6.3)
		Masu	MAY-31-89	20	4.1	0.62	10	-	+	W+R (8.7)
55	Enbetsu	Chum	APR-06-87	35	3.6	0.40	0	-	-	I
56	Mashike	Chum	APR-09-87	10	4.9	1.23	20	-	-	R
57	Hamamashu	Chum	MAR-09-88	62	5.7	1.91	0	-	-	W+R
58	Atsuta	Chum	APR-11-88	53	4.6	0.99	0	-	-	S+R
59	Shikotsuko	Kokanee	APR-16-87	20	2.4	0.08	0	-	-	S
60	Chitose	Chum(A)	JAN-11-82	40	ND	ND	0	-	-	S
		Chum	FEB-09-82	11	ND	ND	100	+	-	S+R
		Chum	FEB-16-82	15	ND	ND	100	+	-	S+R
		Chum	FEB-24-82	20	ND	ND	100	+	+	S+R
		Chum	MAR-02-82	10	ND	ND	60	-	+	S+R
		Chum	MAR-09-82	15	ND	ND	80	-	+	S+R
		Chum	FEB-06-86	60	ND	ND	0	-	-	S
		Chum	MAR-27-86	40	4.6	0.78	48	-	-	S+R
		Chum	MAR-23-87	25	4.3	0.56	20	-	-	S+R
		Chum	MAR-16-88	40	4.1	0.69	18	-	-	S+R
		Chum	MAR-22-88	35	4.2	0.47	17	+	-	S+R
		Chum	MAR-08-89	24	4.1	0.54	21	-	-	S+R
		Masu	APR-26-88	17	5.0	1.14	76	-	-	S+R
		Masu	MAR-09-89	10*	4.2	0.87	90	-	-	S+R

Appendix 1. (continued)

Region No.	Hatchery	Fish species	Collection date	No. fish examined	Mean length (cm)	Mean Weight (g)	Parasites ICH	TRI	CHI	Water supply Type (Temp.)
		Masu	FEB-20-89	10	3.8	0.43	40	-	-	W+R
		Sockeye	APR-12-88	8	11.3	13.23	38	-	-	W+R
		Sockeye	DEC-13-90	7	12.5	18.28	43	-	-	S+R
61	Yoichi	Chum	MAR-19-86	10	3.5	0.26	100	-	+	W+R
		Chum	MAR-11-87	90	3.5	0.39	100	+	-	W+R
		Chum	MAR-09-88	15	3.7	0.30	47	+	-	W+R (6.8)
		Chum	APR-08-88	10	4.5	0.64	100	+	+	W+R (7.7)
		Chum	FEB-01-89	10	3.6	0.28	100	-	+	W+R
		Chum	FEB-22-89	25	3.5	0.39	100	-	-	W+R
		Chum	JAN-19-90	10	3.4	3.17	100	-	+	W+R (8.0)
62	Furubira	Chum	MAR-05-84	19	3.7	0.26	5	-	-	W+R
		Chum(A)	JAN-30-86	20	3.4	0.25	35	-	-	W+R
		Chum	JAN-30-86	20	3.9	0.36	100	-	-	W+R
		Chum	MAR-01-88	30	4.6	1.00	63	-	-	W+R
		Chum	MAR-24-89	15	4.4	0.80	40	-	-	W+R (6.6)
63	Bikuni	Chum(A)	JAN-27-87	60	2.8	0.23	0	-	-	S+R
64	Kamoenai	Chum	MAR-01-87	53	0.8	0.49	0	-	-	S+W (7.0)
65	Iwanai	Chum	MAR-01-87	60	4.2	0.81	0	-	-	R (7.8)
66	Shiribetsu	Chum	MAR-02-87	60	3.4	0.33	0	-	-	S+W+R (6)
		Masu	MAR-02-87	30	3.3	0.39	67	-	-	S+W+R (6)
67	Suttsu	Chum	MAR-02-87	55	3.7	0.30	0	-	-	W+R (5.3)
68	Shimamaki	Chum	MAR-02-87	60	3.4	0.30	0	-	-	W+R (6.5)
69	Setana	Chum	MAR-03-87	60	4.2	0.74	0	-	-	S+R (5.3)
70	Toshibetsu	Chum	MAR-02-87	60	4.3	0.94	0	-	-	S+W (7.0)
71	Kumaishi	Chum	MAR-03-87	60	3.9	0.52	0	-	-	W+R (6.5)
		Masu	MAR-03-87	10	3.8	0.63	0	-	-	W+R (6.5)
72	Ainumanai	Chum	MAR-03-87	65	3.6	0.43	0	-	-	S (5.8)
73	Toppu	Chum(A)	MAR-04-87	52	3.4	0.41	0	-	-	W+R (5.0)
		Masu	MAR-04-87	10*	3.5	0.57	30	-	+	W+R (5.0)
74	Assabu	Chum	MAR-04-87	45	4.0	0.66	0	+	+	W+R (3.0)
75	Kaminokuni	Chum	MAR-04-87	34	4.6	0.93	0	+	-	W+R (6.0)
76	Kiyobe	Chum	MAR-04-87	60	3.8	0.51	0	+	-	R (7.0)
77	Oyobe	Chum	MAR-30-87	30	4.0	0.57	100	-	-	S (7.5)
IV.	**Tsugaru Strait**									
78	Fukushima	Chum	MAR-04-87	60	4.0	0.61	0	-	-	S (7.4)

Appendix 1. (continued)

Region No.	Hatchery	Fish species	Collection date	No. fish examined	Mean length (cm)	Mean Weight (g)	Parasites ICH	TRI	CHI	Water supply Type (Temp.)
79	Shiriuchi	Chum	MAR-05-87	34	5.1	1.35	0	-	-	W+R (6.7)
80	Moheji	Chum	MAR-05-87	42	4.0	0.37	0	-	-	W (8.0)
81	Kamiiso	Chum	MAR-05-87	60	4.2	0.77	0	-	-	W (6.0)
82	Shiodomari	Chum	MAR-05-87	10	4.1	0.61	0	-	-	W (5.8)
83	Haraki	Chum	MAR-05-87	10	4.4	0.88	0	-	-	W+R (2.6)
84	Shirikishinai	Chum	MAR-05-87	10	4.0	0.62	100	-	-	R (6.0)
V.	**Pacific Ocean** (**west**)									
85	Yajiri	Chum	MAR-30-87	30	4.2	0.64	0	-	-	S+R
86	Oofuna	Chum	MAR-05-87	10	3.6	0.41	40	-	-	S+R (4.5)
		Chum	MAR-30-87	10	3.7	0.41	50	-	-	R
87	Shikabe	Chum	MAR-25-86	10	4.7	0.64	70	-	-	R (5.5)
		Chum	MAR-30-87	10	4.1	0.70	100	-	-	R
88	Ojironai	Chum	MAR-30-87	10	3.9	0.54	10	-	-	S+R
89	Yurrapu	Chum	MAR-03-87	30	4.1	0.71	93	+	-	S+R
90	Yakumo	Chum	APR-01-87	29	3.8	0.50	0	-	-	S+W
91	Oshamanbe	Chum	MAR-06-87	10	3.7	0.44	0	-	-	S (10.4)
		Chum	MAR-30-87	20	4.0	0.56	0	-	-	S
92	Nukibetsu #1	Chum	MAR-06-87	15	4.4	0.57	100	-	-	S+W+R (7.2)
93	Nukibetsu #2	Chum	MAR-06-87	15	4.6	0.77	100	-	-	S (8.0)
94	Kesen #1	Chum	MAR-06-87	10	4.4	0.61	0	-	-	S (10.0)
95	Kesen #2	Chum	MAR-06-87	20	3.8	0.38	55	-	-	S+R (3.5)
		Chum	MAR-30-87	10	3.7	0.42	100	-	-	S+R
96	Chimaibetsu	Chum	MAR-06-87	35	4.3	0.46	0	-	-	S+R (5.0)
97	Noboribetsu	Chum	MAR-11-87	60	4.3	0.75	0	-	-	S+R
98	Ayoro	Chum	MAR-11-87	60	4.9	1.15	0	-	-	W+R
99	Shikiu	Chum	APR-24-87	60	5.5	1.62	0	-	-	I+R
		Chum	MAY-09-89	10	6.4	1.94	67	-	-	I+R
100	Shiraoi	Chum	APR-24-87	20	4.2	0.70	90	-	-	I+R
101	Niikappu	Chum	JAN-14-87	30	3.7	0.30	0	-	-	W
102	Shizunai	Chum(A)	JAN-07-87	35	3.3	0.32	0	-	-	W
		Chum	APR-26-87	10	5.4	1.14	100	-	-	W
103	Mitsuishi	Chum	JAN-14-87	40	3.9	0.34	0	-	-	W+I (8.4)
		Chum	APR-15-88	60	3.7	0.43	0	-	-	W+I
104	Motourakawa	Chum	APR-25-87	20	4.7	1.19	65	-	-	I (8.0)
105	Erimo	Chum	APR-25-87	30*	4.6	0.86	13	-	-	W+R

Appendix 1. (continued)

Region		Fish species	Collection date	No. fish examined	Mean length	Mean Weight	Parasites			Water supply
No.	Hatchery				(cm)	(g)	ICH	TRI	CHI	Type (Temp.)
VI.	**Pacific Ocean (east)**									
106	Hiroo	Chum	MAR-24-84	3	4.0	0.38	100	-	-	S+R
		Chum	APR-25-85	10	4.0	0.38	90	-	-	S+R
		Chum	FEB-28-87	5	4.0	0.60	100	-	-	S+R (6.0)
		Chum	APR-19-88	20*	5.3	1.50	35	-	-	R
		Chum	MAR-13-89	10	4.2	0.67	100	-	-	S+I (5.5)
107	Rakko	Chum	APR-25-85	10	4.1	0.42	0	-	-	I
108	Komonbetsu	Chum	APR-13-88	40	4.7	1.06	0	-	-	S
		Chum	APR-26-89	10	4.4	0.88	0	-	-	S (7.9)
109	Taiki	Chum	MAR-24-84	6	ND	ND	50	-	-	I
110	Kousei	Chum	APR-25-85	10	4.0	0.44	50	+	-	R
		Chum	APR-13-88	15	4.2	0.71	100	-	-	I
		Chum	APR-26-89	53	4.6	1.03	0	-	-	I (6.4)
111	Tokachi #1	Chum	APR-18-88	27	4.9	1.16	0	-	-	W+R
112	Satsunai	Chum	MAR-23-84	6	4.4	0.81	17	-	-	W+R
		Chum	MAR-14-89	10	4.7	1.06	0	-	-	W (7.0)
113	Tokachi #2	Chum(A)	MAR-24-84	16	3.8	0.55	0	-	-	W+R
		Chum	APR-18-88	27	4.9	1.16	0	-	-	W
		Chum	MAR-13-89	60	5.2	1.40	80	-	-	W+R (6.8)
114	Ootsu	Chum	MAR-24-84	6	4.6	0.98	100	-	-	S+R
		Chum	MAR-13-89	10	5.0	1.28	0	-	-	S+R (6.9)
115	Makubetsu	Chum	MAR-27-82	15	4.5	0.66	0	-	+	W+R
		Chum(A)	MAR-23-84	36	3.3	0.42	0	-	+	W+R
		Chum	MAR-14-89	10	4.3	0.54	90	-	+	W+R (6.6)
116	Urahoro	Chum	APR-18-89	47	3.9	0.51	0	-	-	R (6.4)
117	Onbetsu	Chum	APR-26-88	44	4.6	0.93	0	-	-	W
118	Tyaro	Chum	APR-26-88	10	4.0	0.61	90	-	-	W+R
119	Shoro	Chum(A)	MAR-24-89	10	3.6	0.41	0	-	-	R (3.0)
		Chum	MAR-14-90	78	3.7	0.43	0	-	-	R
120	Turui #1	Chum	MAR-23-87	10	4.3	0.77	0	-	-	W
		Chum	APR-25-89	10	3.9	0.61	0	-	-	S
121	Turui #2	Chum	MAR-14-89	10	4.0	0.59	0	-	-	W+R
		Chum	APR-25-89	10	4.8	1.18	0	-	-	W+R
122	Ashibetsu	Chum	MAR-23-87	10	3.7	0.43	0	+	-	W+R
123	Kushiro	Chum	MAR-26-82	7	3.7	0.52	14	-	-	S
		Chum(A)	MAR-21-84	15	4.0	ND	0	-	+	S
		Chum	MAY-20-88	20*	4.0	0.51	0	-	-	S

Appendix 1. (continued)

Region		Fish species	Collection date	No. fish examined	Mean length	Mean Weight	Parasites			Water supply
No.	Hatchery				(cm)	(g)	ICH	TRI	CHI	Type (Temp.)
		Chum	MAR-14-89	30	3.9	0.52	0	-	-	S (7.0)
		Masu	AUG-12-88	16	5.2	1.63	100	-	-	S
124	Tyorobetsu	Chum	APR-26-88	20	4.7	1.02	25	-	-	W+R
125	Chyanbetsu	Chum	MAR-22-84	6	3.8	ND	0	-	-	I+R
		Chum	APR-25-88	40*	4.5	0.88	0	-	-	I+R
126	Biwase	Chum	APR-03-89	58	3.6	0.38	0	-	-	S+R (5.5)
127	Shinkawa	Chum(A)	APR-25-88	38	3.3	0.29	0	-	-	R
128	Horoto	Chum	APR-19-89	10	3.6	0.41	0	-	-	R (7.0)
129	Ochiishi	Chum	MAY-11-89	40*	4.1	0.72	0	-	-	R (11.9)

Appendix 2. The occurrence of *Ichthyobodo necator* (ICH), *Trichodina truttae* (TRI) and *Chilodonella piscicola* (CHI) on hatchery-reared juvenile salmonids in northern Honshu.

No.	Region / Hatchery	Fish species	Collection date	No. fish examined	Mean length (cm)	Mean Weight (g)	Parasites ICH	TRI	CHI	Water supply Type (Temp.)
VII.	**Tsugaru Strait and Mutsu Bay**									
1	Masukawa	Chum	MAY-17-88	30	3.9	0.55	0	-	-	R (13.6)
2	Kanita	Chum	MAR-08-88	20	3.7	0.50	25	-	-	W+R (8.6)
3	Nouchi	Chum	MAR-06-89	46	4.4	0.74	0	-	-	W (7.0)
4	Shimizu	Chum	MAR-07-89	30	3.6	0.40	0	-	-	W (9.1)
5	Noheji #1	Chum	APR-02-87	31	4.2	0.66	100	-	-	W+R (9.4)
		Chum	MAR-01-88	30	3.9	0.47	27	-	+	W+I (11.7)
		Chum	MAR-07-89	60	3.7	0.40	0	-	-	W (12.2)
6	Noheji #2	Chum	MAR-09-88	20	3.4	0.40	5	-	-	W+R (8.1)
		Chum	MAR-07-89	30	4.4	0.81	0	+	+	W+R (7.7)
7	Tanabu	Chum	MAR-22-89	30	5.0	1.07	87	-	-	W (12.6)
8	Mutsu	Chum	MAR-23-89	30	4.8	0.94	100	-	-	W (13.6)
9	Kawauchi	Chum	MAR-02-88	40	5.1	1.35	0	-	-	W+I (8.5)
		Chum	MAR-23-89	30	4.4	0.80	100	-	-	W+R (4.2)
10	Oohata	Chum	MAR-01-88	30	3.9	0.58	47	+	-	S+W (7.8)
		Chum	MAR-22-89	30	3.8	0.45	0	+	-	S+W (8.4)
11	Noushi	Chum	MAR-16-88	46	3.7	0.42	0	-	-	W (7.2)
		Chum	MAR-23-89	30	3.7	0.29	0	-	-	W (9.8)
VIII.	**Pacific Ocean**									
12	Oippe	Chum	APR-09-87	30	5.2	1.31	3	+	-	W+I
		Chum	APR-27-87	30	5.0	1.20	43	-	-	W+I
		Chum	MAY-11-88	30	4.8	1.02	0	-	-	I (9.0)
		Chum	MAR-10-89	30	3.9	0.47	100	-	-	W+I (9.8)
13	Rokkasho	Chum	MAR-24-89	30	4.2	0.62	0	-	-	W (10.0)
14	Oirase	Chum	APR-28-87	32	5.5	1.64	0	-	-	W
		Chum	MAR-20-89	30	4.2	0.63	0	+	+	R (7.6)
15	Mabuchi	Chum	APR-15-87	30	5.0	1.26	17	-	-	W+R
		Chum	FEB-29-88	60	4.9	1.18	0	-	-	W+R (5.8)
		Chum	MAR-09-89	30	5.7	1.78	0	-	-	S+R (5.5)
16	Niita	Chum	APR-20-87	29	5.0	1.26	0	-	-	S
		Chum	MAR-09-89	30	5.1	1.37	100	-	-	S (8.4)
17	Uge	Chum	APR-19-90	30	4.2	0.68	0	-	-	W+R (7.9)
18	Takage	Chum	APR-19-90	30	4.0	0.55	0	-	-	R (6.6)
19	Taki	Chum	APR-09-90	30	5.0	1.12	0	-	-	S (8.0)
20	Kokuji	Chum	MAR-07-90	30	4.8	1.13	0	-	-	I (8.3)

Appendix 2. (continued)

Region		Fish species	Collection date	No. fish examined	Mean length	Mean Weight	Parasites			Water supply
No.	Hatchery				(cm)	(g)	ICH	TRI	CHI	Type (Temp.)
21	Noda	Chum	MAY-01-91	30	4.9	1.14	0	-	-	I (8.4)
22	Akka	Chum	MAY-01-91	30	4.1	0.67	0	-	-	I (8.4)
23	Fudai	Chum	APR-24-91	30	4.7	0.90	100	+	-	I (13.3)
24	Akedo	Chum	APR-23-91	40	4.6	0.98	0	-	-	W (12.0)
25	Komoto	Chum	APR-09-90	30	4.5	0.86	0	-	-	W (10.9)
26	Settai	Chum	APR-23-91	30	5.3	1.36	100	-	-	W (9.1)
27	Tarou	Chum	APR-24-91	30	6.0	2.09	0	-	-	I (8.4)
28	Matsuyama	Chum	APR-10-90	30	4.5	0.86	0	-	-	W (7.4)
29	Tugaruishi	Chum	APR-10-90	30	5.8	1.76	0	-	-	W (9.8)
30	Omoe	Chum	APR-20-90	30	4.7	0.93	0	+	-	I (7.4)
31	Oosawa	Chum	APR-10-90	30	5.7	1.64	0	-	-	I+R (12.4)
32	Sekiguchi	Chum	MAR-08-90	30	5.3	1.31	0	-	-	W (9.8)
33	Orikasa	Chum	MAR-08-90	20	5.1	1.13	45	-	-	W (10.8)
34	Ohzuchi	Chum	MAR-08-90	30	5.2	1.58	0	-	-	W (12.2)
35	Kozuchi	Chum	MAR-08-90	30	5.2	1.40	0	-	-	W (10.2)
36	Unozumai	Chum	MAR-13-90	30	4.6	0.89	0	-	-	I (6.0)
37	Kashi	Chum	MAR-13-90	30	5.1	1.31	0	-	-	W (8.5)
38	Katagishi	Chum	MAY-02-91	30	5.3	1.45	0	-	-	I (8.8)
39	Kumano	Chum	APR-10-90	30	5.7	1.72	37	-	-	I (8.1)
40	Yoshihama	Chum	APR-20-90	30	4.3	0.77	0	-	-	I (9.2)
41	Urahama	Chum	MAR-12-90	30	4.4	0.78	0	-	-	I (9.7)
42	Morikawa	Chum	MAR-12-90	30	4.2	0.63	0	-	-	W (10.5)
43	Takada	Chum	MAR-12-90	30	4.8	1.13	0	-	-	I (7.4)
44	Ohkawa	Chum	FEB-14-90	30	4.9	0.97	0	+	-	I+R (10.9)
		Chum	JAN-20-91	20	4.3	0.64	20	+	+	S+R
45	Koizumi	Chum	FEB-16-90	10	4.4	0.83	100	-	-	I (7.2)
46	Yawata	Chum	FEB-16-90	10	4.3	0.69	100	-	-	I+R (6.0)
47	Mizujiri	Chum	FEB-16-90	30	4.5	0.84	0	-	-	I (10.4)
48	Mitobe	Chum	FEB-16-90	30	5.1	1.21	0	-	-	W (11.0)
IX.	**Sea of Japan**									
49	Isomatsu	Chum	MAR-08-88	20	3.4	0.32	50	-	-	G+R (2.7)
		Chum	APR-06-88	20	4.0	0.58	100	-	-	G+R
		Chum	MAR-13-89	30	4.4	0.83	100	-	-	R (5.4)
50	Iwaki	Chum	MAR-14-88	60	4.0	0.63	0	+	+	W (11.7)
		Chum	MAR-06-89	30	4.9	1.05	0	-	+	W (12.3)

Appendix 2. (continued)

Region		Fish species	Collection date	No. fish examined	Mean length	Mean Weight	Parasites			Water supply
No.	Hatchery				(cm)	(g)	ICH	TRI	CHI	Type (Temp.)
51	Akaishi	Chum	MAR-07-88	30	4.5	0.96	0	-	-	W (11.0)
		Chum	MAR-16-88	36	3.9	0.46	0	-	-	W (10.8)
		Chum	JAN-17-91	20	3.4	0.38	55	-	-	W (11.0)
52	Oirase	Chum	APR-16-87	29	4.1	0.66	100	-	-	W+R
		Chum	MAR-15-88	30	4.5	0.87	0	-	-	W+R (5.7)
		Chum	APR-07-88	60	4.3	0.68	0	-	-	W+R (8.0)
		Chum(A)	FEB-28-89	30	3.3	0.30	3	-	-	W+R (7.7)
53	Sasanai	Chum	APR-15-87	30	4.2	0.74	0	-	-	S
		Chum	MAR-15-88	20	4.2	0.68	100	-	-	S (7.1)
54	Ohmine	Chum	FEB-28-89	30	3.3	0.28	0	-	-	R (7.0)
55	Mase	Chum	APR-11-88	16	4.8	0.94	100	-	-	W+R (4-12)
		Chum	APR-11-89	33	4.1	0.70	100	-	-	W+R (4-12)
56	Fujikoto	Chum	APR-12-88	20	4.4	0.75	0	-	+	S (7.5-8.5)
		Chum	APR-11-89	34	4.5	0.95	0	-	-	S (7.5-8.5)
57	Ani	Chum	APR-11-88	20	4.8	1.05	0	-	-	W (7-14)
		Chum	APR-11-89	23	5.1	1.25	100	-	-	W+R (7-8.6)
58	Nomura	Chum	APR-11-88	20	4.6	0.94	0	-	-	W+R (6.5-11)
		Chum	APR-04-89	29	4.0	0.61	0	+	-	W+R (6-11)
59	Omono	Chum	APR-08-88	20	4.7	1.07	100	-	-	W+R (5-12.1)
		Chum	MAR-30-89	60	4.6	0.83	0	-	-	W (8.5-10.9)
60	Kimigano	Chum	APR-08-88	20	4.1	0.53	100	-	-	S+R (4.5-10)
		Chum	APR-06-89	10	4.0	0.52	100	-	-	W (8-8.9)
61	Koromo	Chum	APR-08-88	21	4.2	0.74	0	-	-	W+R (5-10)
		Chum	APR-06-89	23	4.2	0.71	0	-	-	W+R (5-10)
62	Ishizawa	Chum	APR-08-88	20	5.1	1.06	0	-	-	S+R (6.5-10)
		Chum	APR-06-89	20	4.6	1.03	100	-	-	I+R (6.5-10)
63	Ayu	Chum	APR-08-88	17	4.0	0.65	100	-	-	W+R (4-12)
		Chum	APR-06-89	16	3.8	0.55	0	-	-	W+R (4-12)
64	Nishime	Chum	APR-08-88	16	3.9	0.56	94	-	-	W+R (5-10)
		Chum	APR-05-89	41	4.2	0.64	0	-	-	W (5-10)
65	Akaishi	Chum	APR-08-88	20	4.9	0.94	0	-	-	W+R (5-12)
		Chum	MAR-28-89	20	5.3	1.49	0	-	-	W+R (8.9-13.1)
66	Kawabukuro	Chum	MAR-31-88	27	6.3	2.43	0	-	-	S (8.5-11)
		Chum	APR-09-88	20	5.3	1.40	0	-	-	S (8.5-11)
		Chum	MAR-28-89	23	5.4	1.74	0	-	-	S
		Chum	APR-05-89	21	5.1	1.23	0	-	-	S (8.6-9.8)
67	Naso	Chum	MAR-18-88	20	4.7	1.03	5	-	-	W+R (6-12)

Appendix 2. (continued)

Region No.	Hatchery	Fish species	Collection date	No. fish examined	Mean length (cm)	Mean Weight (g)	Parasites ICH	TRI	CHI	Water supply Type (Temp.)
		Chum	APR-05-89	25	4.1	0.65	100	-	-	W+R (6-12)
68	Zougata	Chum	APR-08-88	21	5.2	1.30	0	-	-	S (9.5-10)
		Chum	APR-05-89	42	4.6	0.99	0	-	-	S (10.0)
69	Minowa	Chum	MAR-23-90	65	5.5	1.59	0	+	-	S+R (10.5)
70	Masu	Chum	MAR-28-90	60	5.3	1.36	60	-	-	S+W (9.0)
71	Gakko	Chum	MAR-28-90	59	5.7	1.79	0	+	-	S+R
72	Takase	Chum	MAR-28-90	60	6.5	2.52	0	-	-	W+R (13.0)
73	Nikko	Chum	MAR-20-90	30	5.0	1.15	0	+	+	W+R (12.2)
74	Aka	Chum	MAR-12-90	60	5.9	1.99	0	-	-	W (11.7)
75	Sanze	Chum	MAR-30-90	30	7.4	3.73	0	-	-	W