Summary of Parasite and Epizoit Investigations during JARPN Surveys 1994-1999, with Reference to Stock Structure Analysis for the Western North Pacific Minke Whales

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ABSTRACT

The investigations on parasites and epizoits of the western North Pacific minke whales were carried out during JARPN surveys from 1994 to 1999. Data from a total of 498 whales examined were summarized and analyzed to determine the migrants from the Sea of Japan (J-stock) in the Sea of Okhotsk and to differentiate a currently proposed stock (W-stock) from the western North Pacific population (O-stock). Analyses were made mainly by comparisons of the occurrences of parasites (prevalence) and the frequency distributions of numbers of parasites (intensity) for three species, *Lecithodesmus goliath* (Trematoda), *Anisakis simplex* (Nematoda) and *Pennella balaenoptera* (Copepoda). The mitochondrial DNA haplotypes were also referred to interpret the result. J-stock whales are characterized by a low prevalence *P. balaenoptera*. W-stock could not be differentiated from O-stock because no area-

specific parasite was found and regional differences in prevalence and intensity of parasites were not so large to identify W-stock.

INTRODUCTION

The investigations on parasites and epizoits of the western North Pacific minke whales (*Balaenoptera acutorostrata*) were carried out during JARPN surveys from 1994 to 1999 (Fujise *et al.*, 1995, 1996, 1997, 2000; Ishikawa *et al.*, 1997; Zenitani *et al.*, 1999). As an initial step of the investigation, we reported an important role of minke whales as final hosts of the stomach nematode, *Anisakis simplex*, final hosts of which had been believed to be small cetaceans (Kagei *et al.*, 1967), on the high seas of the western North Pacific (sub-area 9) by using samples obtained in JARPN 1994 (Kuramochi *et al.*, 1996). Sequentially, we represented the first report of the parasite fauna of the western North Pacific minke whales caught in sub-area 9 in JARPN 1995 (Araki *et al.*, 1997) because only limited faunal information had been available (e.g., Kamo *et al.*, 1969, 1980; Yamaguti, 1939, 1941). Moreover, in JARPN 1996, the faunal study areas covered the offshore and coastal waters of the western North Pacific (sub-areas 8 and 7W, respectively) and the southern Sea of Okhotsk (sub-area 11) and we described the histopathological changes due to parasite infestation (Uchida *et al.*, 1998).

The object of JARPN surveys is to analyze the stock structure of the western North Pacific minke whales using several different methods. Parasites contain potential utility as biological indicators and have been used for stock identification of aquatic organisms (MacKenzie, 1987; Pascal and Hochberg, 1996; Nagasawa *et al.*, 1998). Also in case of marine mammals, several parasites have been used as stock indicators of cetaceans (Walker, 1981, 1987, 1990; Mead and Potter, 1990; Dailey and Vogelvein, 1991; Balbuena *et al.*, 1995). A total of 498 minke whales from both the western North Pacific and the southern Sea of Okhotsk were examined during JARPN surveys in 1994-1999 and data on the occurrence of the parasites and epizoits were accumulated. We herein summarize the parasitological data and try to find useful parasites or epizoits as biological indicators for stock structure analysis of the western North Pacific minke whales.

For the western North Pacific minke whales, two distinct populations occurring each in the western North Pacific Ocean and the Sea of Okhotsk (O-stock) and in the Sea of Japan (J-stock) have been hypothesized. For the latter stock, Goto and Pastene (1997) revealed that some minke whales migrate from the Sea of Japan into the Sea of Okhotsk based on haplotype analyses using the mitochondrial DNA (mtDNA) control region. Moreover, a new stock, namely W-stock occurring on the high seas of the western North Pacific, has been currently proposed (IWC, 1994a). Based on these backgrounds, in the present paper, we focus on both identification of J-stock whales in the Sea of Okhotsk and detection of W-stock in the offshore western North Pacific by using parasites and epizoits.

MATERIALS AND METHODS

After a preliminary JARPN survey in 1994, three of the authors (JA, AU and TK) were engaged in an extensive survey on the parasites and epizoits on board the mother ship during JARPN surveys in 1995-1997 with co-operation of the researchers of the Institute of Cetacean Research (ICR). Methods used for parasitological examination were described by Araki *et al.* (1997). In 1998 and 1999 surveys, ICR researchers conducted both data collections and samplings of voucher specimens based on a manual described by one of the authors (KN). In brief, the whole body surface of whales was examined for ecto- and mesoparasites and epizoits; every stomach chamber was examined for recording the occurrence of stomach nematodes; bile ducts were observed for trematodes by slicing the liver in 10 cm thickness; a 1.5-m portion of the small intestine was collected from both ends and opened to detect cestodes and acanthocephalans, which were also searched when the internal surface of the small intestine was turned outside for making the food product (*hyakuhiro*). Parasitological examinations were carried out by the naked eyes. Counting for mesoparasites were made throughout the surveys except for 1994. Liver flukes were also counted in 1995, 1996 and 1997. The stomach nematodes for numerical analyses were collected in 1995, 1997 and 1999.

Data sets from a total of 498 minke whales were grouped by the following manner and expressed as prevalence (percentage of hosts infected with given parasite or epizoit), intensity (number of parasites or epizoits in a single host) and mean intensity (average number of parasites or epizoits per infected hosts) as described by Margolis *et al.* (1982). First, these data were divided by sub-area, such as 7W, 7E, 8, 9 and 11 (IWC, 1994b), and prevalences were compared to find parasites and epizoits which show approximate regional differences. Second, reproductive conditions of the minke whales examined were considered for analysis to rule out host-age related differences in prevalence. Data on the sexual maturity of each minke whale were supplied from ICR. Prevalences were compared between immature and mature whales by sex and by sub-area. If some differences were found, mature male whales were used for further analysis because mature males were most abundantly sampled. Third, differences in prevalence between survey months and years were examined by sub-area. If no difference was found, they were combined to determine prevalence for each sub-area, which was used for further analysis. In addition, intensity data were also used for analysis when available. For study of J-stock whales, the results given by Goto *et al.* (2000) was referred to. They represented a cluster of minke whales, which possibly had migrated from the Sea of Japan into the southern Sea of Okhotsk (sub-area 11), determined by the mtDNA control region sequences. Comparisons in prevalence ware made by sub-area for O-stock whales to examine whether W-stock is actually present. Prevalence was statistically compared by using Fisher's exact probability test (p=0.05) when sample size was small, and chi-square test for larger sample size.

RESULTS

Prevalence and mean intensity of parasites and epizoits obtained from the western North Pacific minke whales during JARPN surveys from 1994 to 1999 are summarized in Table 1. As previously reported by Araki *et al.* (1997) and Uchida *et al.* (1998), six species of endoparasites, *Lecithodesmus goliath* van Beneden (Digenea: Camplidae), *Diphyllobotrium macroovatum* Jurachno, 1973, *Diplogonoporus balaenopterae* Lönnberg, 1892 (Cestoda: Diphyllobothriidae), *Tetrabothrius* sp. (Cestoda: Tetrabothriidae), *Anisakis simplex* (Rudolphi, 1809)(Nematoda: Anisakidae) and *Bolbosoma nipponicum* Yamaguti, 1939 (Acanthocephala: Polymorphidae), one mesoparasite, *Pennella balaenoptera* Koren and Danielssen, 1877 (Copepoda: Pennellidae), one ectoparasite, *Cyamus balaenopterae* Barnard, 1931 (Amphipoda: Cyamidae) and two epizoits, *Conchoderma virgatum* Spengler, 1790 (Cirripedia: Lepadidae) and *Xenobalanus globicipitis* Steenstrup, 1851 (Cirripedia: Balanidae) were found in or on minke whales from the western North Pacific and the southern Sea of Okhotsk. No area-specific parasite or epizoit showing a high prevalence was found. Prevalence of *L. goliath* found in the bile ducts and *P. balaenoptera* on the body surface somewhat differed among sub-areas (37.1-81.3% for *L. goliath* and 65.0-79.7% for *P. balaenoptera*). Although *A. simplex* and *B. nipponicum* showed high prevalence (almost 100%) in all sub-areas, prevalence of *A. simplex* was 76.7% for sub-area 11 in 1996. Prevalence of cestodes (three species combined), *C. balaenopterae*, *C. virgatum* and *X. globicipitis* were too low to analyze. Thus, data on three species (i.e., *L. goliath*, *A. simplex* and *P. balaenoptera*) were used in the following analyses. Catch localities of minke whales and occurrence of these parasites are shown in Figs. 1-3.

Consideration of host maturity and preparation of prevalence data by sub-area

Prevalence of *L. goliath* was higher in mature whales (45.5-91.2% for males and 33.3-100% for females) than in immature ones (0-35.7% for males and 0-80% for females) in almost all sub-areas. Significant difference was mainly found in males, while sample size was small for females. Therefore, we use mature males for analysis of prevalence of *L. goliath.*

Similarly, prevalence of *P. balaenoptera* was higher in mature males (61.9-80.0%) than in immature ones (20.0-63.6%), although the difference was not significant, except for sub-area 8. In females, prevalence varied due to small sample size, but it was very low in both mature and immature whales in sub-area 11 (25.0% for immatures and 19.1% for matures) and sub-area 9 (36.4% for immatures and 38.5% for matures), where relatively large number of females were obtained. Then, we tentatively used mature males for analysis of prevalence of *P. balaenoptera.*

Comparisons in monthly prevalence were made using data from mature males by survey year and by sub-area, but no significant differences were found in any case for both *L. goliath* and *P. balaenoptera* (data not shown). Prevalence was thus combined by year and compared again by sub-area to represent regional data, and significant differences were found among annual data in sub-areas 8 and 9 for *L. goliath* and sub-areas 8 and 11 for *P. balaenoptera.* In these cases, annual prevalence from each sub-area was not combined and used for analysis independently.

As mentioned above, prevalence of *A. simplex* was almost 100% except for sub-area 11 in 1996. Therefore, analysis was slightly different. During JARPN surveys from 1994 to 1999, 14 minke whales were found uninfested by *A. simplex* (one from both sub-area 7W and 8, four from sub-area 9 and eight from sub-area 11). These whales included only two immature whales, which were not infested by only *A. simplex* nor also other parasites and epizoits, and were caught in May 1997 in southern portion of sub-area 9. The remaining 12 whales composed of nine mature males and three mature females. Intensity of *A. simplex* was available from 29 whales (four from sub-area 9 in 1995 [Araki *et al.*, 1996], one from sub-area 7E, 12 from sub-area 8, four from sub-area 9 in 1997, and 16 from sub-area 11 in 1999). These whales composed of three immature and 18 mature males and one immature and eight mature females. They were used for analyses irrespective of maturity and sex because of small sample size.

Analyses for J-stock in sub-area 11

The minke whales obtained from sub-area 11 were divided into two groups, i.e. assumed migrants from the Sea of Japan (J-stock) and those from the western North Pacific population (O-stock) based on the results given by Goto *et al.* (2000). The composition of sex and maturity of J-stock whales was 12 males and 10 females as mature animals and one male and two females as immature animals. Because of their larger numbers, only mature males and females were used for comparison.

Prevalences of *L. goliath* in mature males and females from J-stock were 81.8% (N=11) and 50.0% (N=10), respectively, and those from O-stock were 83.9% (N=31) and 90.9% (N=11), respectively. No significant difference was found between whales from both stocks, even though mature males and females of each stock were combined.

On the contrary, prevalence of *P. balaenoptera* in the assumed migrants from J-stock was strikingly low. Twenty-four whales were found uninfected with *P. balanoeptera* irrespective of maturity and sex (except for one mature male caught in 1996) and overall prevalence was quite low (4.0%) in contrast to that (60.0%) for O-stock. Of *Pennella*–uninfected minke whales collected from sub-area 11, 64.7% of mature males (N=17) and 58.8% of mature females (N=17) were assumed to have come from J-stock. Goto *et al.* (2000) assumed that migrants form J-stock to sub-area 11 had been dominated by mature males for 1996 and by mature females for 1999. This assumption well corresponds to our finding that prevalence in sub-area 11 was lower in 1996 (41.2%) than in 1999 (76.0%), when we compared prevalence in mature males before separating both stocks. Therefore, prevalence in whales of O-stock from sub-area 11 was calculated again after excluding those whales that were assumed to have come from J-stock. For 1996 and 1999, 60.0% (N=10) and 90.5% (N=21) were recorded from mature males, and 50% (N=6) and 20% (N=5) from mature females, respectively. This difference between 1996 and 1999 was not significant in both mature males and females. These results were used in the following analysis.

As in sub-area 11 seven whales (five mature males and two mature females) were not infested by *A. simplex* in 1996, a low prevalence of 70.8% was recorded for mature animals (both sexes combined), in contrast to almost 100% in the western North Pacific sub-areas. However, only one uninfested whale was taken from sub-area 11 in 1999, and prevalence was recorded as 97.6%. These eight infested whales were divided into two, namely the putative migrants each from J-stock and O-stock. To define the whales from J-stock, intensity data on *A. simplex* were used. The number of worms from 17 whales obtained from the western North Pacific sub-areas in 1997 was summed by each stomach chamber (i.e., forestomach, fundic chamber, pyloric chamber and duodenal ampulla [Olsen *et al.*, 1994]) and was estimated as 1,253, 34,770, 4,036 and 162, respectively. Therefore, 86.4% of worms were found in the fundic chamber. Also prevalence in the fundic chamber was higher (96.5%) than in other sites (45.1% for the forestomach, 62.5% for the pyloric chamber, 33.1% for the duodenal ampulla) when data from all minke whales examined were combined. Thus, intensity in the fundic chamber was used for comparison. Intensity of *A. simplex* in the fundic chamber of 37 whales examined was plotted using the latitude of catch locality of whales for X-axis (Fig. 4). There was no tendency to isolate the J-stock derivatives from the members of O-stock. Moreover, intensities were fitted in a significant simple regression line ($p<0.05$), indicating that whales caught in more northerly areas show higher intensity, although the regression coefficient was low (r=0.53).

Analyses for separation of W-stock from O-stock

Prevalences of *L. goliath* in mature males are shown by survey year and sub-area in Fig. 5, where assumed whales of J-stock were excluded from sub-area 11. As mentioned above, since annual data in sub-area 8 for 1996, 1997 and 1998 and in sub-area 9 for 1995 and 1997 showed significant differences by sub-area, these data were not combined and used for regional comparison in prevalence. Prevalence was significantly higher (91.2%) in sub-area 7W than in sub-area 8 (64.3% for 1996 and 72.4% for 1997). In sub-area 9, prevalence was low (37.5% for 1995 and 60.5% for 1997) and the values for these years significantly differed from those in all other sub-areas (82.5% for sub-areas 7W and 7E in 1997 and 1998, 91.4% for sub-area 8 in the same years, and 83.9% for sub-area 11 in 1996 and 1999 combined). To determine detailed regional differences in prevalence, the whales were divided by catch localities. Prevalences are shown for every five degrees of the latitude and longitude in Fig. 6, where whales assumed to have migrated from J-stock were excluded. Significant decrease in prevalence was found between regions separated by a line along 155° E, located in the eastern portion of sub-area 8. When whales were divided into two groups based on this longitude, there was significant difference in prevalence between the western (80.3%, N=61) and eastern sides (50.7%, N=146). We then used data on intensity for analysis, too. A Wilcoxon signed-ranks test was applied to analyze the frequency distributions of intensity in these two groups (Fig. 7), but it failed to differentiate them ($p>0.05$).

Prevalences of *P. balaenoptera* are shown by survey year and sub-area in Fig. 8. When annual data were compared by sub-area, a significant difference was found again in sub-area 8 (69.0% for 1997 and 94.3% for 1998), as in case of *L. goliath*. On the other hand, annual difference found in sub-area 11 was resolved by excluding the whales from J-stock. Overall prevalences were 70.2%, 90.0%, 79.2% and 80.6% for sub-areas 7W, 7E, 9 and 11, respectively. Prevalence in sub-area 8 for 1998 was significantly different from those in sub-areas 7W and 9, but that in sub-area 8 for 1997 was significantly lower than that in sub-area 7E. There was also a significant difference in prevalence between sub-areas 7W and 7E. Prevalence recorded from sub-area 11 did not show any difference from those from other sub-areas, and it thus may be regarded as a baseline of O-stock. Detailed regional comparisons in prevalence were made by dividing whales for every five degrees of the latitude and longitude (Fig. 9). Although a slight increase in prevalence was observed from the coastal to offshore waters at 40-45° N, there was no significant difference in any combinations. Thus, we tuned back sub-areal comparison and used intensity data for analysis. Significant difference was found in only two pairs, sub-areas 7W and 7E, and sub-areas 7W and 9 (Mann-Whiteney's *U*-test, $p<0.05$). However, comparisons of the relative frequency distributions (Fig. 10) did not detect any significant difference (Wilcoxon signed-ranks test, $p>0.05$).

DISCUSSION

In this study, no area-specific parasite or epizoit was found. Therefore, we analyzed prevalence and intensity of three species of parasites, *L. goliath*, *P. balaenoptera* and *A. simplex* to ensure the migration of J-stock minke whales from O-stock into sub-area 11 (the southern Sea of Okhotsk) and to differentiate W-stock from O-stock in the western North Pacific sub-areas. Through haplotype analyses of mtDNA control region, Goto and Pastene (1997) revealed that two stocks are genetically differentiated and may mix in the southern Sea of Okhotsk. Furthermore, these authors succeeded in categorizing major haplotypes of J-stock minke whales into one cluster and make possible to putatively determine that individuals belong to J-stock derivative or another (Goto *et al.*, 2000).

Referring to their theory, we first analyzed parasitological data obtained from sub-area 11. Although *L. goliath* was not useful to separate these two stocks, *P. balaenoptera* showed obvious differences in prevalence between whales from J-stock and O-stock. Prevalence of this parasite in J-stock was recorded as 4% in this study, being much lower than 70-90% for O-stock. This mesoparasite is visible on the body surface of whales and one of the largest parasitic copepods (about 15 cm in length). About 60% of whales that have not been infested with *Pennella* in sub-area 11 were regarded as migrant from O-stock, and the absence of this parasite may be useful for preliminary identification of J-stock, although accuracy is not necessarily high. This result also supports the hypothesis proposed by Goto *et al.* (2000). Meanwhile, some of the clustered major haplotypes of J-stock were exceptionally possessed by a small number of whales from the western North Pacific sub-areas. The percent occurrence of such whales was 5% in sub-area 7 and 8 and 1.6% in sub-area 9. These whales showed approximately the same level of infestation by *P. balaenoptera* as the others in these sub-areas, suggesting that they have spent for a relatively long time in the western North Pacific, although they were born as a member of J-stock.

It was one of our major interests that prevalence of *A. simplex* in sub-area 11 in 1996 was lower than that in other sub-areas. In 1999, however, it was unexpectedly almost the same level as that in the western North Pacific sub-areas. Although four of eight whales without *A. simplex* infestation were regarded as migrants from J-stock, the other whales possessed a quite common haplotype which is found in whales from the western North Pacific. The life cycle of this nematode is documented well (Køie *et al.*, 1995; Nagasawa, 1990). *A. simplex* uses euphausiids as intermediate hosts, and its infective larvae are accumulated in paratenic hosts, such as fishes and squids feeding on euphausiids. Minke whales can be parasitized by *A. simplex* by eating both intermediate and paratenic hosts, and the rate of infestation appears to be closely related with food habits of host animals. Minke whales are known to opportunistically consume euphausiids, squids and fishes in the western North Pacific, but they highly depend on euphausiids in the southern Sea of Okhotsk (Fujise, 1996, 1997; Tamura, 1998; Tamura *et al.*, 1998). Although food habits of minke whales in the Sea of Japan are still unknown, we believed that the infestation level of *A. simplex* should have been lower in the whales from sub-area 11 because whales from J-stock migrated there. To elucidate this, we analyzed intensity of *A. simplex* using data on the count of worms found in the fundic chamber of 21 O-stock whales caught in the western North Pacific sub-areas, and 10 O-stock and six J-stock individuals obtained in sub-area 11. The fundic chamber is known as the main habitat of *A. simplex* (Uchida *et al.*, 1998) in contrast to the forestomach in small cetaceans (Kagei *et al.*, 1967). Intensity in the whales from sub-area 11 was not actually low and comparable to that from the western North Pacific sub-aeras. Thus, we failed to divide the whales into stocks by using the data on *A. simplex*. This result may suggest that the food-web system utilized by minke whales is more complex than that in appearance also in sub-area 11.

The existence of W-stock was inquired using *L. goliath* and *P. balaenoptera* based on comparisons of prevalence and the frequency distribution of intensity. Prevalences of both species in sub-area 8 for 1998 were protruded beyond the other two research years. Prevalence of *L. goliath* in sub-area 9 also differed between 1995 and 1997. These differences probably due to shift in catch localities of whales by year. In sub-area 8, the research whaling was conducted mainly in more western part in 1998 than in 1996 and 1997. The catch localities of whales in sub-area 9 were more northerly in 1995 than in 1997. Regional differences in prevalence varied, ranging from 37.5% to 91.4%for *L. goliath* and from 69.0% to 94.3% for *P. balaenoptera* . Prevalences of *L. goliath* were 80.3% and 50.7% in the eastern and western portions divided by a line 155° E, respectively. However, these differences are too small to separate stocks and seem to be due to differences in abundance of larval stages of these parasites in intermediate hosts. The life cycles of these parasites are still unknown. However, marine digeneans in general need marine snails as the first intermediate hosts and use fishes as the second ones. So far it is known, pennellid copepods also possess two-host life cycle (Kabata, 1992) and members of the genus *Pennella* need cephalopods as intermediate host (Nagasawa *et al.*, 1985). Walker (1990) reported regional variation in prevalence of *Crassicauda* sp. (Nematoda: Crassicaudidae) parasitic in Dall's porpoise (*Phocoenoides dalli*), recording 31.0% in the Bering Sea, 96.1% in the western North Pacifc and 100% in the Sea of Okhotsk. However, he neglected this parasite from the analysis to separate the Bering Sea stock because he thought that the differences in prevalence were not great. In addition, we compared the regional frequency distributions of intensity of *L. goliath* and *P. balaenoptera.* This method is useful for regional comparisons when intensity of parasites were available (Nagasawa *et al.*, 1998). Although we employed non-parametric statistical test due to small sample size, no regional difference was found for these two parasites. These results suggest that W-stock cannot be separated from O-stock by *L. goliath* and *P. balaenoptera.*

We conclude that *P. balaenoptera* may be useful to determine J-stock whales in the southern Sea of Okhotsk, and that W-stock is not defined by parasites, because no area-specific parasite was found to differentiate W-stock from O-stock and regional differences in prevalence and intensity of parasites were not so large to identify W-stock.

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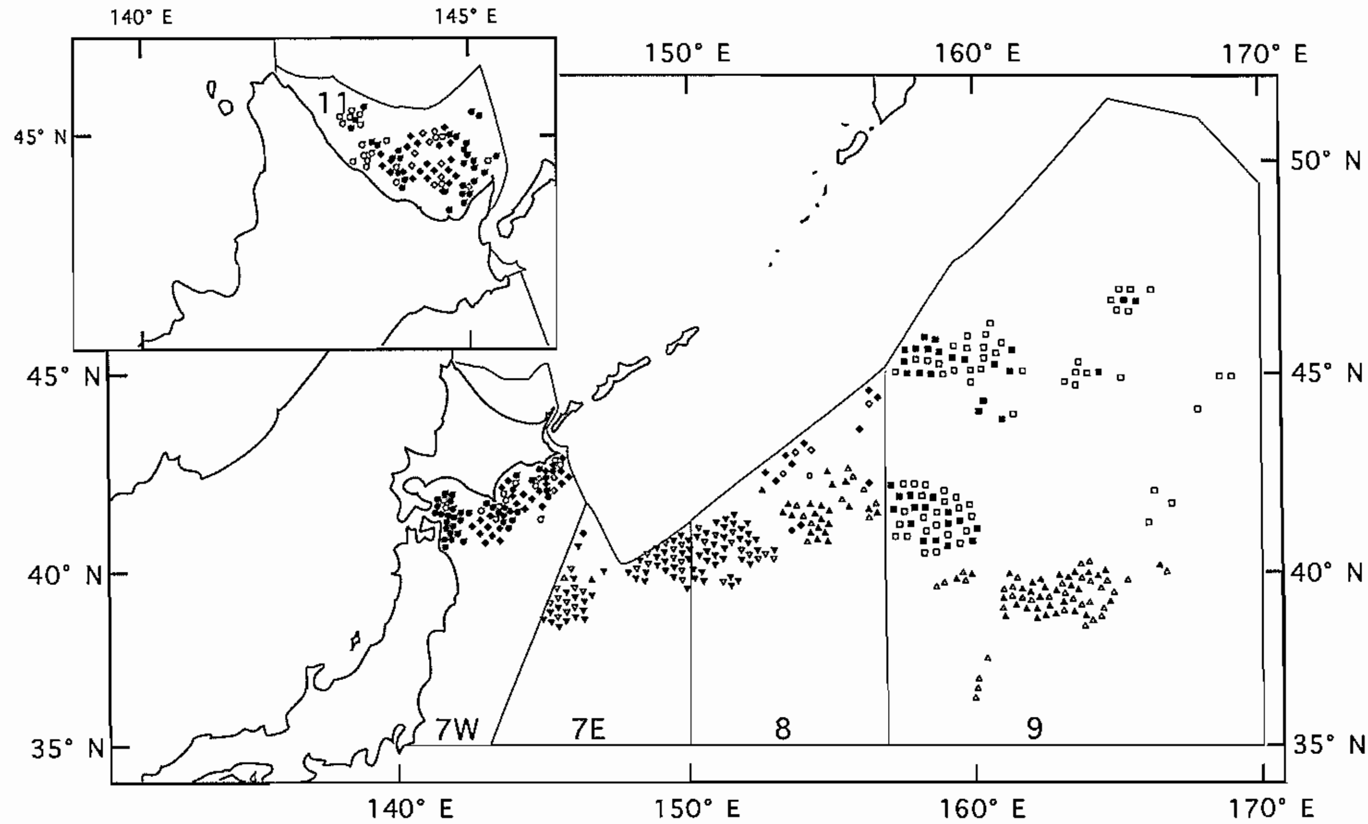

Fig. 1. Occurrence of *Lecithodesmus goliath* in the northern North Pacific minke whales. Closed and opened symbols indicate the whales infested and uninfested by *L. goliath* , respectively. Squares, 1995; diamonds, 1996; triangles, 1997; reversed triangles, 1998; circles with bar. 1999.

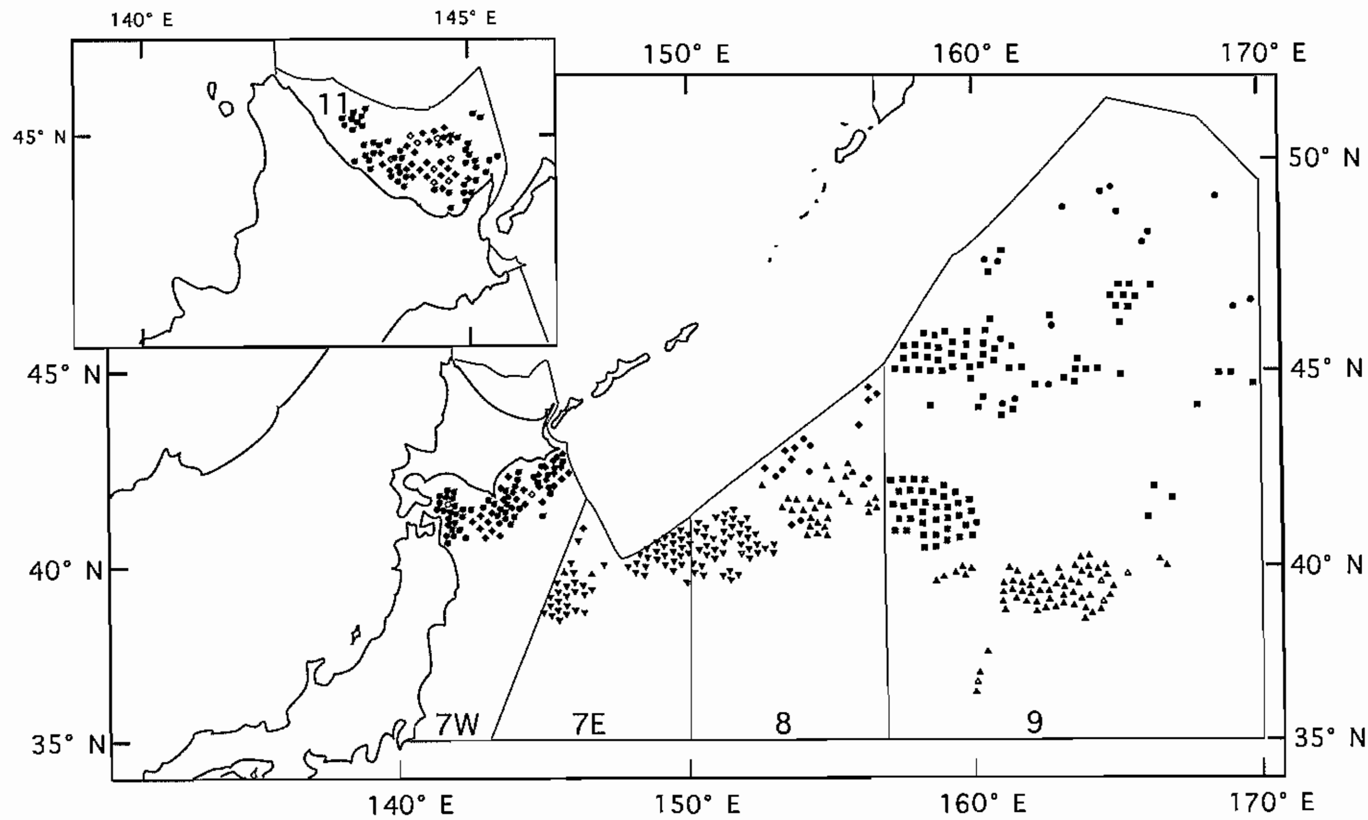

Fig. 2. Occurrence of *Anisakis simplex* in the western North Pacific minke whales. Closed and opened symbols indicate the whales infested and uninfested by *A. simples*, respectively. Circles, 1994; squares, 1995; diamonds, 1996; triangles, 1997; reversed triangles, 1998; circles with bar. 1999.

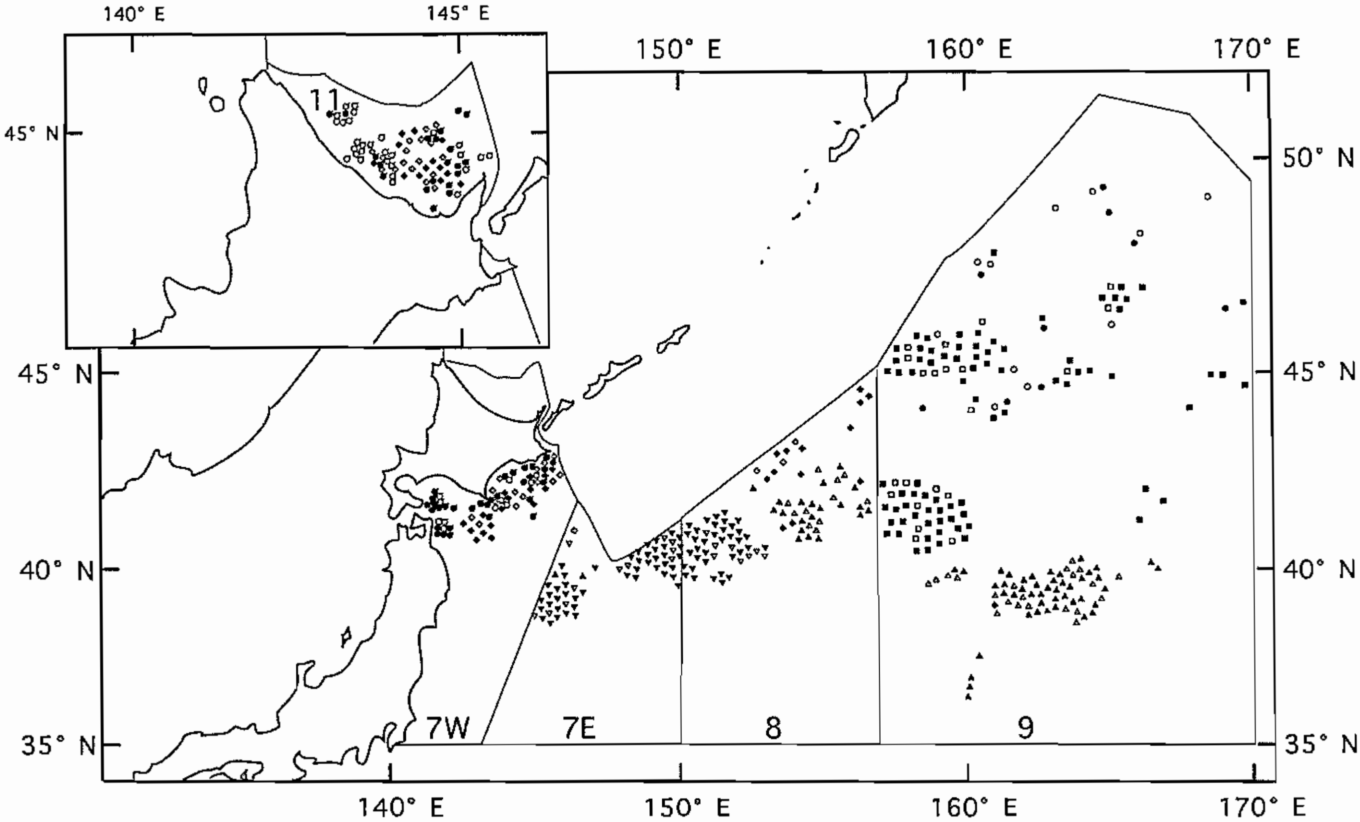

Fig. 3. Occurrence of *Pennella balaenoptera* in the western North Pacific minke whales. Closed and opened symbols indicate the whales infested and uninfested by *P. balaenoptera*, respectively. Circles, 1994; squares, 1995; diamonds, 1996; triangles, 1997; reversed triangles, 1998; circles with bar, 1999.

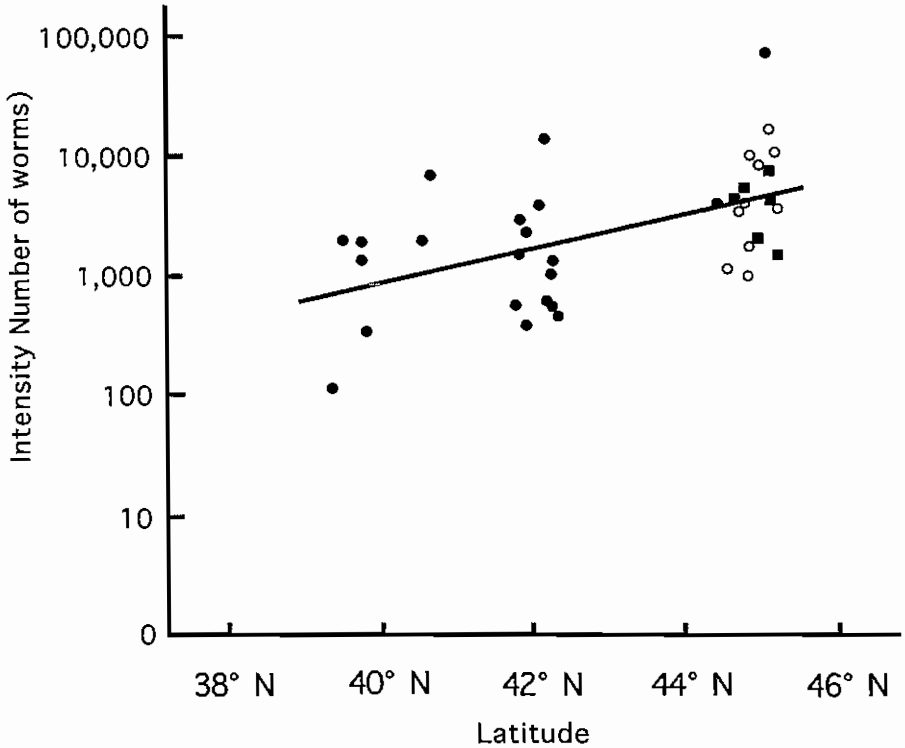

Fig. 4. Relation between intensity of *Anisakis simplex* and the latitude of catch locality in the western North Pacific minke whales caught in 1995, 1997 and 1999. Closed circles, whales caught in the western North Pacific sub-areas; open circles, O-stock whales from sub-area 11; closed squares, migrants from J-stock in sub-area 11.

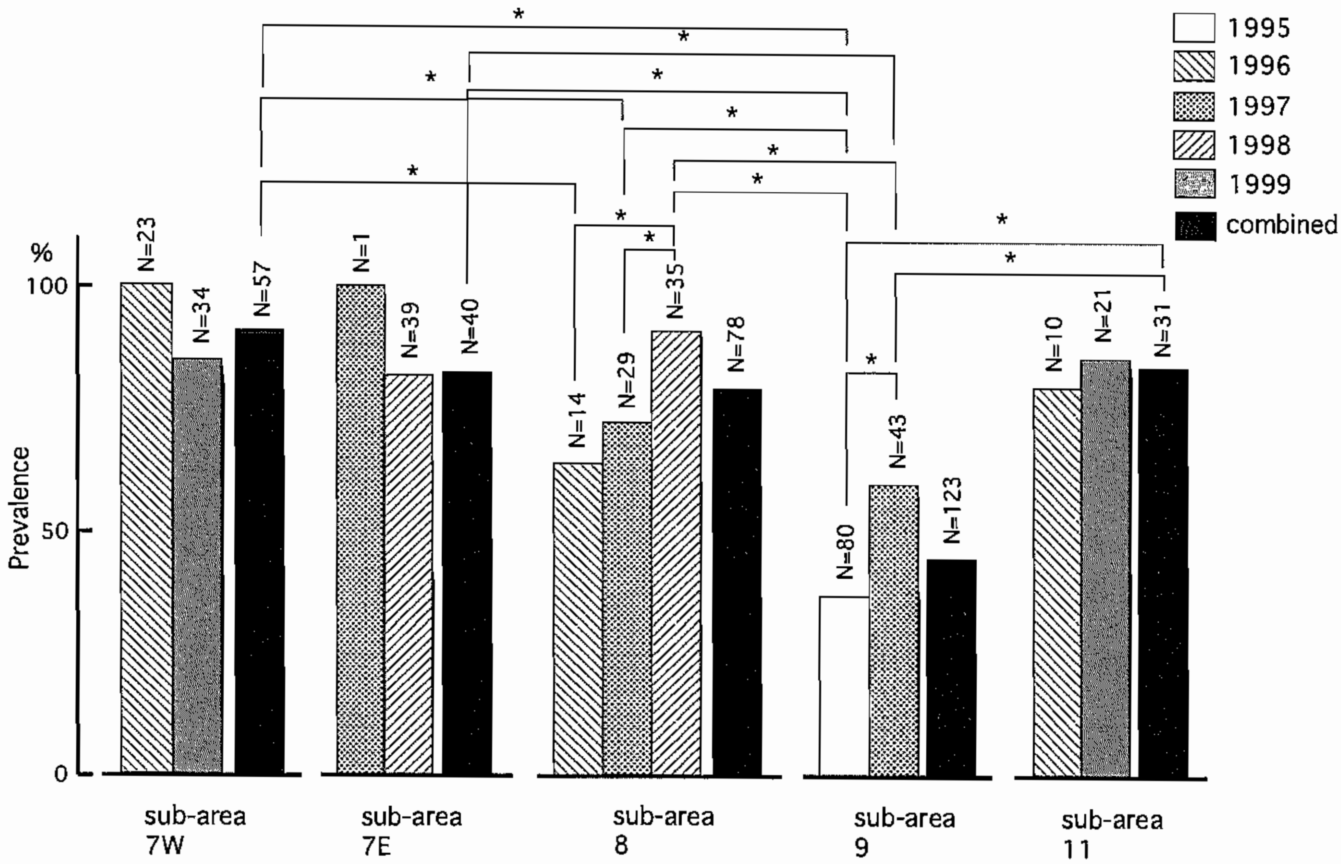

Fig. 5. Prevalence of *Lecithodesmus goliath* in the western North Pacific minke whales by survey year and sub-area. Significant differences in prevalence by paiwise comparisons are indicated by asterisks.

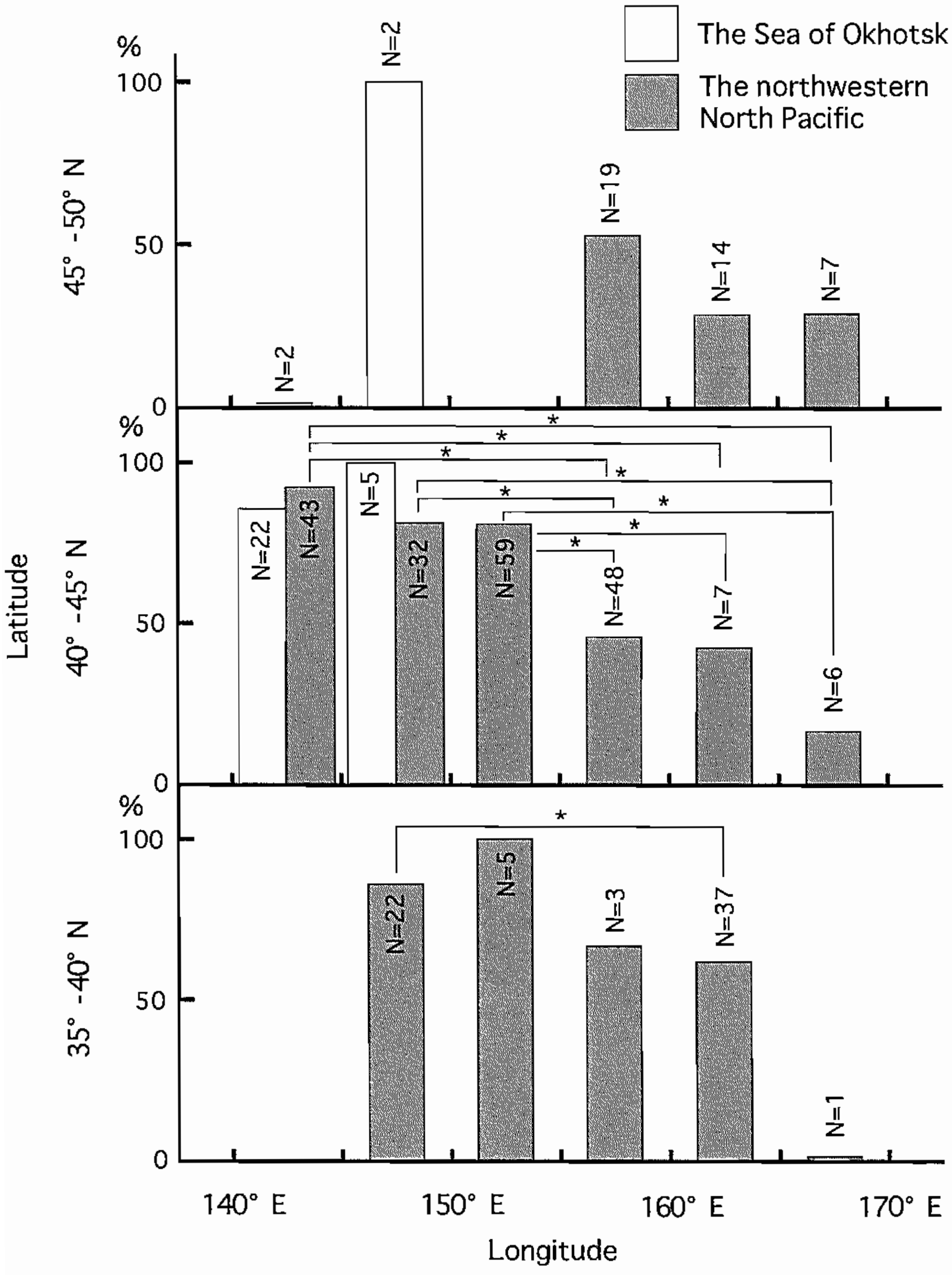

Fig. 6. Prevalence of *Lecithodesmus goliath* in the western North Pacific minke whales (mature males) by every five degrees of the latitude and longitude. Significant differences in prevalence by pairwise comparisons are indicated by asterisks.

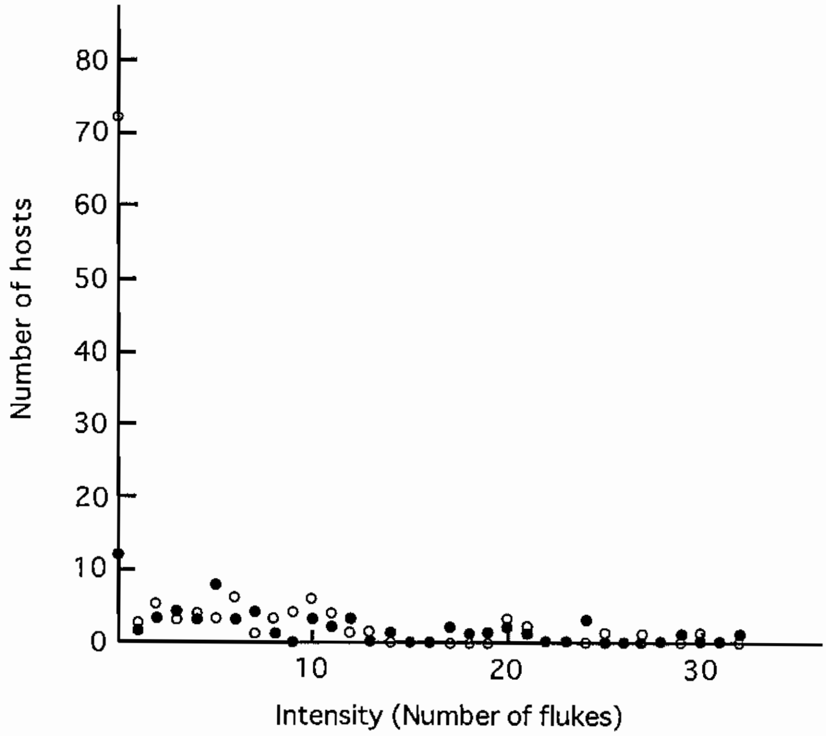

Fig. 7. The frequency distribution of intensity of *Lecithodesmus goliath* in the western North Pacific minke whales from the western side (closed circles) and the eastern side (open circles) of 155° E in the western North Pacific.

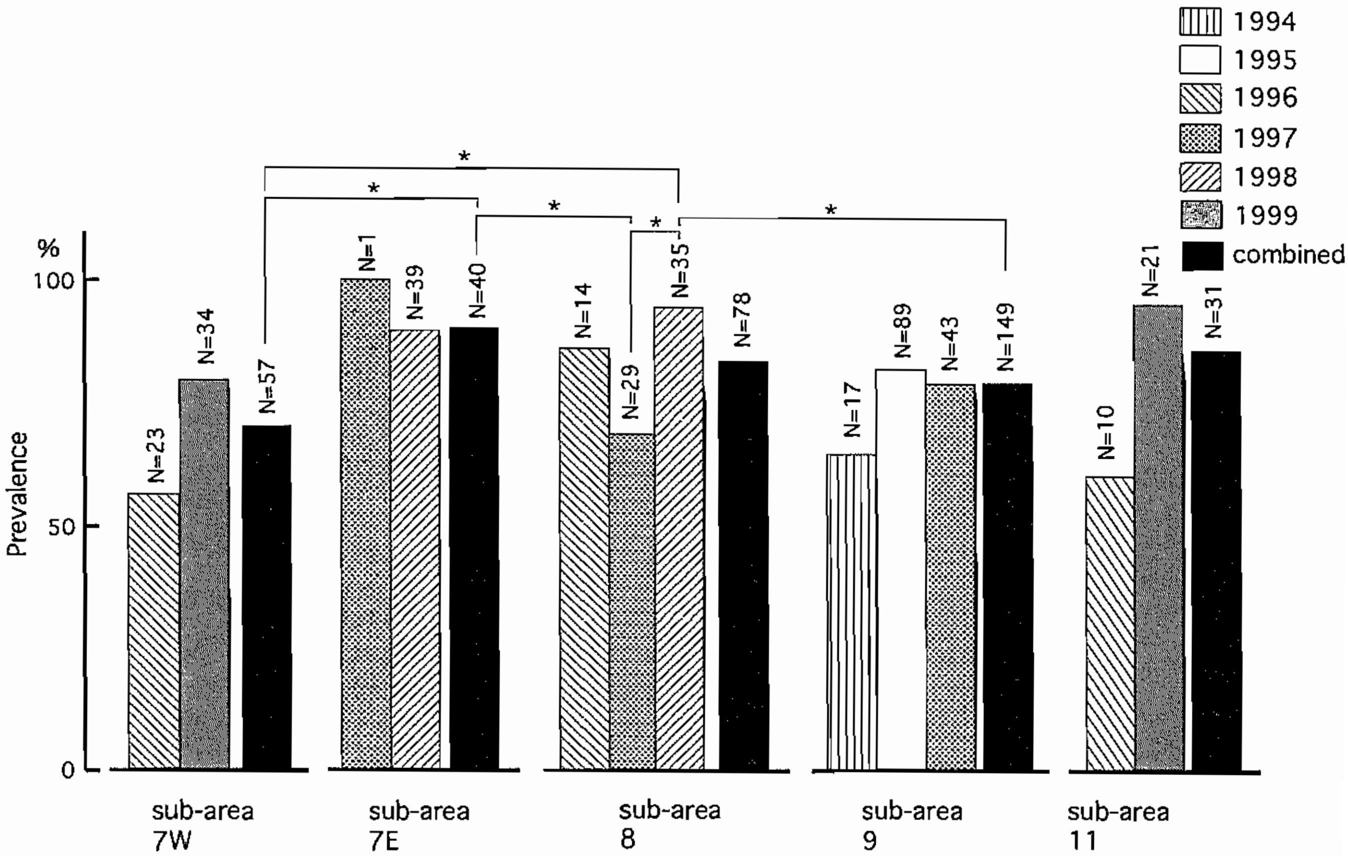

Fig. 8. Prevalence of *Pennella balaenoptera* in the western North Pacific minke whales by survey year and sub-area. Significant differences in prevalence by pairwise comparisons are indicated by asterisks.

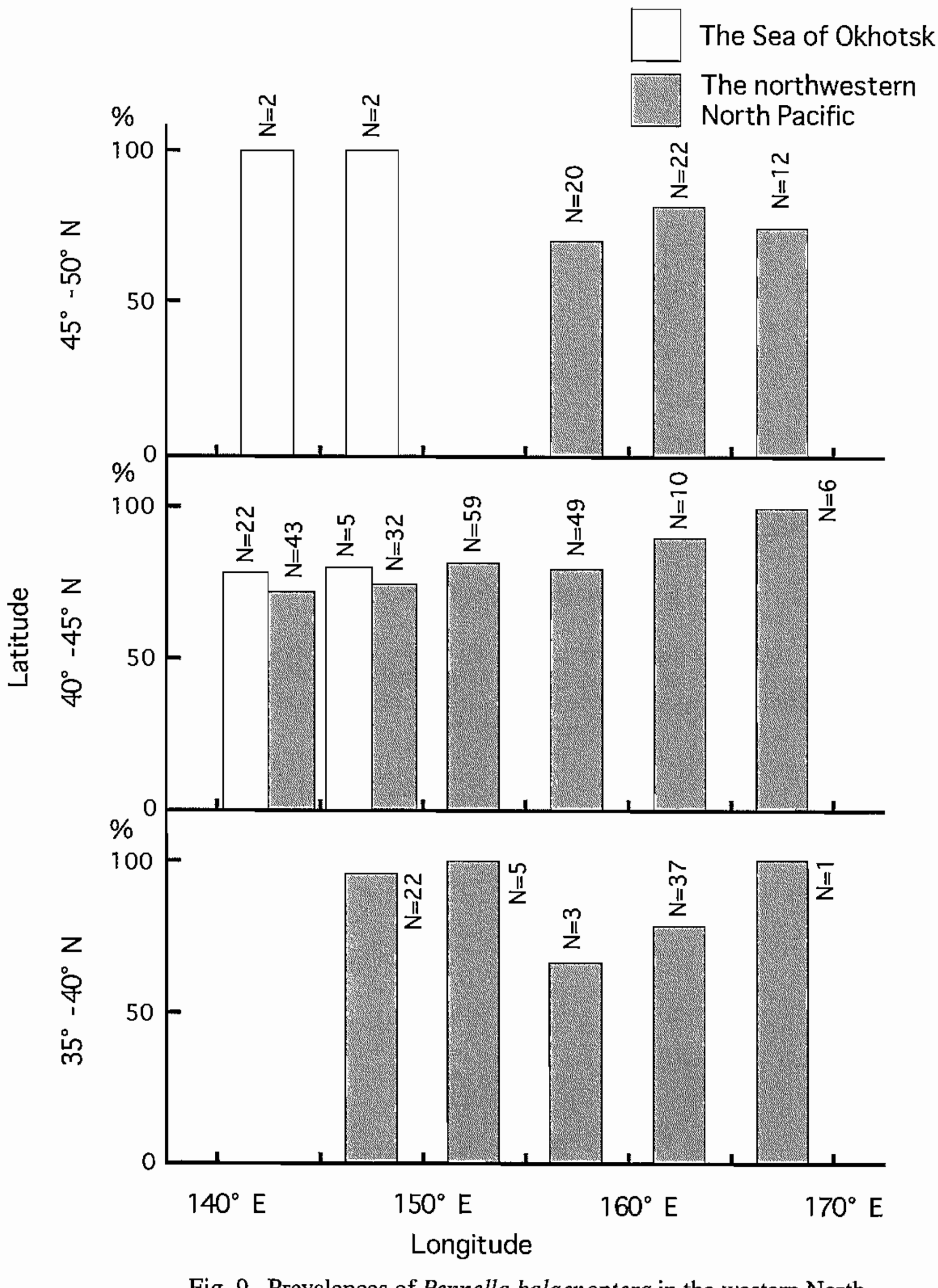

Fig. 9. Prevalences of *Pennella balaenoptera* in the western North Pacific minke whales (mature males) by every five degrees of the latitude and longitude. No significant difference is found in any pairwise comparison.

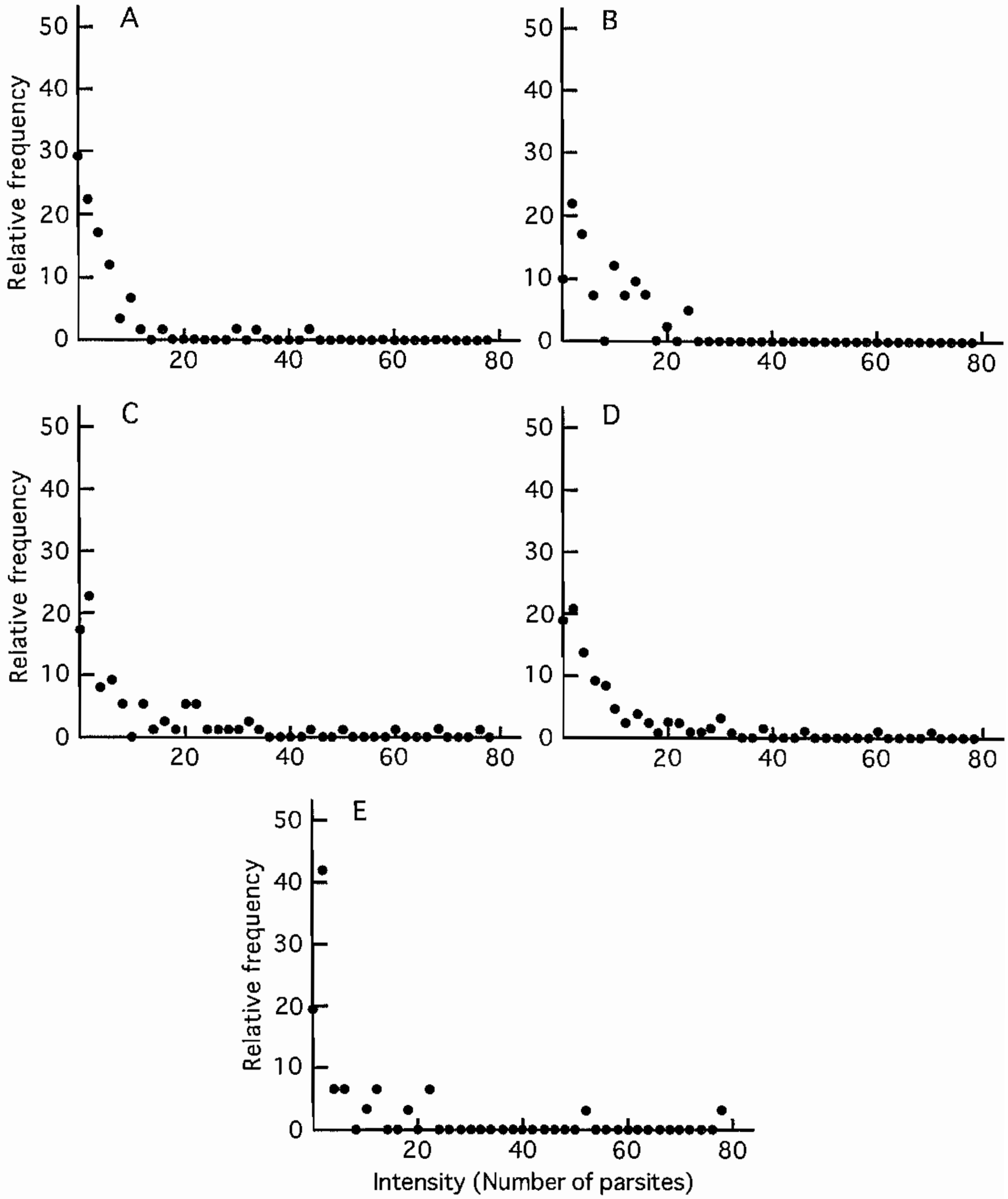

Fig. 10. The relative frequency distribution of intensity of *Pennella balaenoptera* in the western North Pacific minke whales. A, sub-area 7W; B, sub-area 7E; C, sub-area 8; D, sub-area 9; E, sub-area 11.

Table 1. Prevalence and mean intensity of parasites and epizoits in the northern North Pacific minke whales examined during JARPN surveys1994-1999 by sub-area, year and month.

Sub-area	Year	Month	No. of whales	*Lecithodesmus goliath*		Cestodes	*Anisakis simplex*	*Bolbosoma nipponicum*	*Pennella balaenoptera*		*Cyamus balaenopterae*	*Conchoderma virgatum*	*Xenobalanus globicipitis*
				*Mean intensity	**Prevalence	Prevalence	Prevalence	Prevalence	Mean intensity	Prevalence	Prevalence	Prevalence	Prevalence
7 W	1996	Aug.	15	13.3	100.0	0.0	100.0	100.0	6.8	66.7	6.7	13.3	0.0
		Sep.	15	11.4	80.0	6.7	93.3	100.0	22.2	40.0	6.7	0.0	6.7
	1996 combined		30	12.4	90.0	3.3	96.7	100.0	12.6	53.3	6.7	6.7	3.3
	1999	Jun.	50	N.E.	76.0	8.2	100.0	98.0	6.5	72.0	2.0	4.0	14.0
	combined		**80**	**12.4**	**81.3**	**6.3**	**98.7**	**98.7**	**8.4**	**65.0**	**6.3**	**5.0**	**8.8**
7 E	1996	Jul.	1	3.0	100.0	0.0	100.0	100.0	N.E.	0.0	0.0	0.0	0.0
	1997	Jun.	2	6.0	50.0	50.0	100.0	100.0	11.5	100.0	0.0	0.0	0.0
	1998	May	56	N.E.	64.3	15.6	100.0	100.0	8.0	80.4	1.8	1.8	5.4
	combined		**59**	**4.5**	**64.4**	**14.1**	**100.0**	**100.0**	**8.1**	**79.7**	**1.7**	**1.7**	**5.1**
8	1996	Jul.	11	3.3	54.5	0.0	100.0	100.0	12.8	72.7	0.0	36.4	9.1
		Aug.	5	5.0	80.0	0.0	100.0	100.0	10.6	100.0	0.0	40.0	0.0
	1996 combined		16	4.0	62.5	0.0	100.0	100.0	11.7	81.3	0.0	37.5	6.3
	1997	Jul.	31	8.1	67.7	17.2	100.0	100.0	18.6	64.5	0.0	3.2	16.1
	1998	May	8	N.E.	87.5	12.5	100.0	100.0	16.3	100.0	0.0	0.0	0.0
		Jun.	36	N.E.	77.8	12.1	97.2	100.0	9.8	77.8	0.0	2.8	2.8
	1998 combined		44	N.E.	75.0	12.2	97.7	100.0	11.3	81.8	0.0	2.3	2.3
	combined		**91**	**7.3**	**70.3**	**11.6**	**98.9**	**100.0**	**13.5**	**75.8**	**0.0**	**8.8**	**7.7**
9	1994	Jul.	8	N.E.	N.E.	0.0	100.0	100.0	N.E.	37.5	25.0	0.0	0.0
		Aug.	9	N.E.	N.E.	0.0	100.0	100.0	N.E.	66.7	11.1	0.0	0.0
		Sep.	4	N.E.	N.E.	0.0	100.0	100.0	N.E.	50.0	25.0	0.0	0.0
	1994 combined		21	N.E.	N.E.	0.0	100.0	100.0	N.E.	52.4	19.0	0.0	0.0
	1995	Jun.	14	N.E.	25.0	21.4	100.0	100.0	6.2	85.7	0.0	0.0	0.0
		Jul.	61	11.8	45.9	11.5	100.0	100.0	10.3	73.8	4.9	4.9	1.6
		Aug.	25	5.7	24.0	24.0	100.0	100.0	9.1	84.0	4.0	0.0	0.0
	1995 combined		100	10.0	37.8	16.0	100.0	100.0	9.3	78.0	4.0	3.0	1.0
	1997	May	27	10.0	40.7	16.0	85.2	92.3	14.6	74.1	0.0	7.4	3.7
		Jun.	40	11.6	52.5	28.2	100.0	100.0	7.7	65.0	2.5	7.5	7.5
	1997 combined		67	11.0	47.8	23.4	93.9	97.0	10.7	68.7	1.5	7.5	6.0
	combined		**186**	**10.6**	**37.1**	**16.8**	**97.9**	**98.9**	**9.8**	**71.8**	**4.8**	**4.3**	**2.7**
11	1996	Aug.	30	5.9	70.0	21.4	76.7	100.0	11.5	43.3	6.7	6.7	0.0
	1999	Jul.	50	N.E.	62.0	21.4	98.0	100.0	9.0	42.0	2.0	0.0	6.0
	combined		**80**	**5.9**	**65.0**	**21.4**	**89.9**	**100.0**	**9.9**	**42.5**	**5.0**	**1.3**	**3.8**
All combined			**498**	**9.7**	**60.6**	**14.8**	**97.2**	**99.4**	**10.1**	**67.7**	**3.8**	**4.4**	**5.0**

* Mean intensitiy indicates average numbers of parasites or epizoits per infected hosts.

** Prevalences indicates percentage of hosts infected with given parasite or epizoits.

N.E.: not examined.