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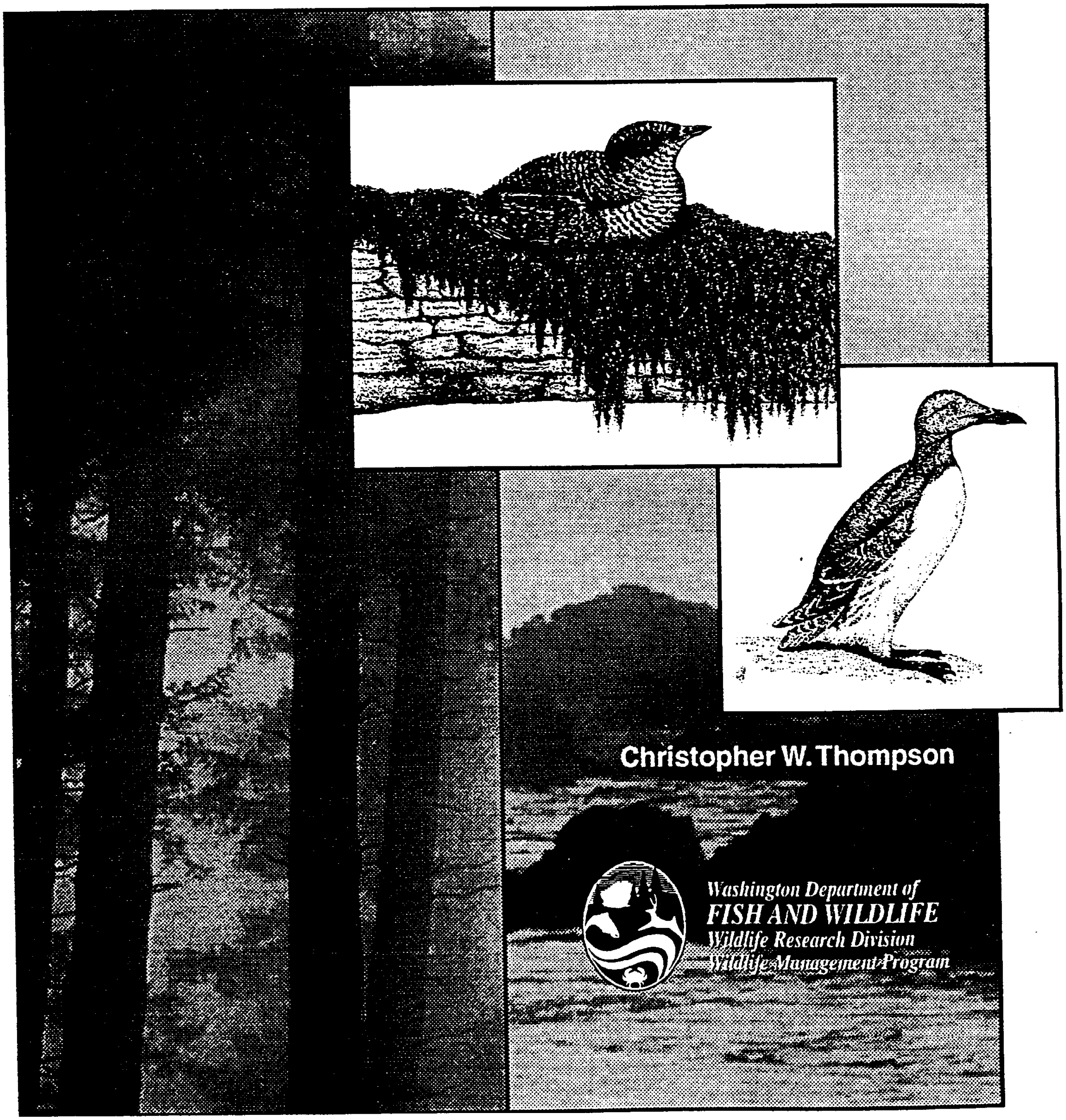
Distribution and Abundance of Marbled Murrelets and Common Murres on the Outer Coast of Washington – 1997 Completion Report to the Tenyo Maru Trustee's Council



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Completion Report to the *Tenyo Maru* Trustee's Council

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Executive Summary

The *Tenyo Maru* Trustee's Council funded Washington Department of Fish and Wildlife to accomplish three tasks with respect to Marbled Murrelets, *Brachyramphus marmoratus*, and Common Murres, *Uria aalge*: (1) determine their at sea distribution and abundance, including development of methods to accurately do so, (2) determine whether presence of kelp influences the distribution or abundance of adult or juvenile Marbled Murrelets, and (3) determine if Common Murres are breeding at locations on the Washington coast other than Tatoosh Island (the largest and best studied breeding colony in Washington).

The distribution and abundance of Marbled Murrelets (hereafter murrelets) appears to be fairly stable throughout the summer within and between years. In summer, they are most numerous along the Strait of Juan de Fuca, less numerous on the northern outer coast from Neah Bay south to Copalis, and rare to nearly absent in most areas south of Copalis, including Gray's Harbor (except at its mouth), Willipa Bay and the Columbia River. This pattern of murrelet distribution and abundance is positively correlated with kelp distribution, and also appears to be correlated with the distribution of rocky vs. sandy coastline and benthic substrate, and with the proximity to nesting areas (old growth forest), although these latter two correlations are tentative and require more quantitative analyses. In winter however, their numbers decrease dramatically along the entire Washington coast. In contrast, the distribution and abundance of Common Murres (hereafter murres) is considerably more temporally and spatially variable. Murres breed in huge numbers in Oregon (approx. 800,000) relative to Washington (<10,000), and in summer and fall large numbers of "Oregon" murres migrate north along the Washington coast and the Strait of Juan de Fuca, an unknown proportion of them reaching Puget Sound. This results in large absolute and relative changes in abundances of murres throughout Washington waters. Annual variation in breeding phenology and reproductive success at Oregon murre colonies results in corresponding annual variation in the timing, intensity and size of the northward movement of murres into Washington waters. Like murrelets, the abundance of murres decreases dramatically along the entire Washington coast in winter. Where murres and murrelets go in winter and why is completely unknown.

Analyses to help develop and improve our sampling methodology indicate that, independent of distance from shore, murrelets are most abundant early in the morning and decrease throughout the day whereas murres show no detectable change in abundance with time of day. In addition, independent of time of day, murrelets are most numerous close to shore (200-400 meters) and at shallow depths (usually <15 meters), and are rarely found at or beyond 1200 meters or at depths exceeding 15 meters. In contrast, murres are most abundant between 1000 meters and 2500 meters from shore, but their abundance does not appear to be correlated with water depth. Together, these results suggest that different survey methods are necessary for monitoring murrelet and murre abundance.

Juvenile murrelets were estimated to comprise approximately 17% of murrelets surveyed (in the Strait of Juan de Fuca) in summer 1996. This is an extremely high rate of productivity. Possible explanations for this result are discussed. Surveys at sea of areas with and without visible surface kelp were done to evaluate the feasibility of using such focal observations for counting murrelets and observing their behavior. This method causes too much disturbance, and thus is not a viable sampling strategy. Rectilinear surveys at sea were conducted around a known breeding colony (Tatoosh Island) and a "control" site to determine whether the distribution and abundance patterns of murres under these two conditions can be used as a useful indicator of breeding at potential breeding colonies (e.g., Grenville complex, Quilleute Needles). Our results corroborate and expand on previous findings by J. Parrish. They indicate that such surveys may be a useful criterion to indicate breeding, and that the ideal time to conduct such surveys is in the morning, preferably in late May to late June.

Future plans are discussed to (1) evaluate the influence of kelp on juvenile vs. adult murrelets, (2) further evaluate the merits of zig-zag versus parallel transects for counting murres and murrelets, (3) do a power analysis to determine the average number of transects necessary to detect specified changes in murre and murrelet density over user-defined time intervals, (4) evaluate the relative merits of line vs. strip transects for counting murrelets, (5) use GIS databases of the distribution of old growth forest and shoreline/benthic substrate structure to analyze the correlation between the distribution and abundance of murres and murrelets and these factors, and (6) conduct land-based and surveys at sea of the Grenville complex (and possibly the Quilleute Needles) to determine whether murres are breeding at these sites.

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Introduction

Washington Department of Fish and Wildlife (WDFW) was funded by the *Tenyo Maru* Trustee's Council to address three questions of concern: (1) what is the distribution and abundance of Common Murres, *Uria aalge*, and Marbled Murrelets, *Brachyramphus marmoratus*, on the outer coast of Washington (Port Angeles west to Neah Bay and Tatoosh Island, and south to the Columbia River), including continued development of survey methods for doing so, documentation of immigration of Common Murres (hereafter murres) from Oregon into Washington, and correlation of habitat parameters with murre and Marbled Murrelet (hereafter murrelet) distribution and abundance, (2) is murrelet distribution, abundance or behavior influenced by the presence or absence of kelp, and (3) are murres breeding at Washington localities other than Tatoosh Island (the largest and best studied murre breeding colony in Washington) as they are known to have done historically (e.g., at Point Grenville complex and/or Quilleute Needles)?

Objective 1: At-sea distribution and Abundance of Common Murres and Marbled Murrelets

The justification for collecting data regarding distribution and abundance of murres and murrelets is that these data can be used as population indices to monitor increases or decreases in these species in the area affected by the Tenyo Maru oil spill. However, these data can only be used in this way if they are sufficiently accurate for changes of user-specified magnitude to be statistically detectable. Unfortunately, methodologies for accurately counting these species at sea are poorly developed. Thus, a prerequisite to to collecting meaningful distribution and abundance data is the development of an appropriate methodology for counting these species at sea. One goal of all censusing or sampling methodologies is to reduce sources of variability in the data in order to maximize the probability of discriminating changes over time with a minimum of time, effort, and expense. For the purpose of designing a sampling methodology for murres and murrelets, the most important factors to understand are those that investigators have the most control over, and thereby can reduce variation in, e.g., time of day and distance from shore at which surveying is conducted. In addition, however, it is also critical to determine how murre and murrelet distribution and abundance is affected by biotic and abiotic environmental factors over which we have less control from the standpoint of survey design, e.g., water depth, presence/absence of surface and/or submergent vegetation, benthic substrate structure, water temperature and salinity, prey abundance etc. The results of our efforts to develop a sampling methodology suitable for murres and murrelets are presented under "Task 3" below.

Specific tasks funded:

(1) Determine summer and winter distribution and abundance, including post-breeding northward immigration of dad-chick murre pairs from Oregon.
(2) Correlate behavioral data (e.g., feeding, diving, sitting, flying, in single/mixed species flock) with habitat parameters.

(3) Correlate abundance and distribution of murres and murrelets with habitat parameters by conducting replicate sets of transects in different habitats and by correlating distribution and abundance data with GIS databases.

(4) Estimate murrelet productivity by measuring adult:juvenile ratio.

Progress to Date

Task 1

Within- and between season abundance and distribution. Our data indicate that in the summer of 1996 murrelets were most numerous along the Strait of Juan de Fuca, less numerous on the northern outer coast, and rare along the southern outer coast (discussed further below, figures 1-7). A similar pattern was observed in the summer of 1995 (figure 10), including concentrations of murrelets at the mouths, or to the south of, the Hoh and Quinault Rivers, and to a much lesser extent the Copalis River; however, murrelets were more scarce (i.e., nearly absent) from Copalis south to the Columbia River in summer 1995 than in summer 1996. Their summer abundance and distribution appears to be correlated with proximity to old growth forest and to rocky shoreline/substrate vs. sandy shoreline/substrate, although these apparent correlations require more quantitative analyses (discussed below). Murrelet abundance and distribution (summer and winter) also is correlated with distribution of *Nereocystis* and *Macrocystis* kelp (discussed below).

In winter (figure 11), murrelet abundance decreases dramatically along the entire Washington coast except for an apparent increase in density at the mouth of Gray's Harbor. This in interesting because, in winter, a lower percentage if any murrelets are visiting old growth forest, i.e., most or all murrelets are on the ocean. So, this raises the obvious question: If they are not near the Washington coast, where have they gone and why?

The pattern of distribution and abundance of murres is more complex, partly due to progressive changes in their distribution and abundance caused by northward migration of murres from Oregon in late summer. Murres fledge from breeding colonies in Oregon in late June or early July, on average, and disperse as far north as Cape Flattery and the outer Strait of Juan de Fuca by late July. In contrast, Washington murre colonies do not fledge until early August or later. As a result, the distribution and abundance pattern of murres changes over the course of the summer. In early summer 1996 (May-June, figure 8), murres were most numerous along the southern coast (south of Gray's Harbor), and were nearly absent from much of the northern coast (e.g. Copalis River to Hoh River). By late summer (July and August, figure 9), murres had become more abundant along both the southern coast and northern coast, indicating a northward wave of murres immigrating into Washington from the south. A similar pattern was observed in the summer of 1995. In that season, we only surveyed late in the summer (31 July through 20 September), and found that murres were more numerous along the northern coast (excluding Tattosh Island and surrounding waters) than along the southern coast (figure 12), suggesting that most of the murres immigrating into Washington from the south had already passed the southern coast and reached at least as far north as the Quinault River. Murres are numerous in the vicinity of Tatoosh Island, and for some distance to the south of it, throughout the summer (figures 8, 9, 12).

As with murrelets, murre abundance decreases dramatically along the entire Washington coast, including Tatoosh Island, in winter (figure 13). This also raises the question stated above for murrelets: If they are not near the Washington coast, where have they gone and why?

Murre immigration from Oregon. Murres experienced nearly complete reproductive failure in Oregon in the summer of 1996 (K. Warheit, J. Grettenberger pers. comm.). As a result, despite intensive surveying (Tables 1-2) of the southern Washington coast to detect dad-chick pairs and/or chicks immigrating from Oregon, we saw only 8 chicks (apparently by themselves) and one dad-chick pair out of 8844 observations of 37,332 murres in summer 1996. The sightings were as follows:

Date	General location	Chick or Dad-Chick
24 July	Port Angeles - Sekui	Dad-chick
30 July	Leadbetter Pt - Columbia River	Chick
30 July	Leadbetter Pt - Columbia River	Chick
6 August	Port Angeles - Sekui	Chick
8 August	Port Angeles - Sekui	Chick
8 August	Port Angeles - Sekui	Chick
8 August	Port Angeles - Sekui	Chick
8 August	Port Angeles - Sekui	Chick
9 August	Port Angeles - Sekui	Chick

The two chicks observed on the southern coast (between Leadbetter Point [Willapa Bay] and the Columbia River) could not have come from Tatoosh Island because no chicks had fledged from Tatoosh that early. Although they might have come from other Washington localities, it seems more likely that they came from Oregon, despite the nearly total reproductive failure in Oregon. Because of intense Bald Eagle disturbance on Tatoosh Island, reproduction was delayed and protracted resulting in later than average fledging of chicks, the earliest known fledging date being 11-12 August (J. Parrish unpubl. data). Thus, the other chicks and single dad-chick pair observed in the Strait of Juan de Fuca also did not originate from Tatoosh Island, but probably originated from Oregon colonies as well.

Task 2

Behaviors of all birds were noted and classified into one of the following categories: (1) sitting on the water, (2) diving (usually associated with feeding, but could be avoidance of observers in some cases), (3) feeding, (4) flying, and (5) flushed. The software developed jointly by Ecological Consulting Incorporated (Portland, OR) and WDFW to analyze our raw data still have a few glitches in them, one of them being that the behavior data are not imported from the raw data files into subsequent database files. This software problem has recently been resolved; as a result, we will soon analyze the behavioral data with respect to habitat parameters (especially kelp presence/absence), and possibly other factors.

Task 3

Understanding how murres and murrelets use Washington outer coast habitats is essential for (1) development of a valid and accurate method for surveying for these species, and (2) determining whether any component of these habitats can be manipulated as part of a restoration plan. We defined "habitat" as any environmental variable that can influence murre or murrelet distribution, and includes bathymetry, distance from shore, water salinity and temperature, type and amount of surface and/or submergent vegetation, etc. Understanding *how* these seabirds use these habitats is just as important as understanding *whether* they use these habitats.

Based on a review of the literature on seabird censusing methodology, murres, and murrelets, we identified time of day, distance from shore, water depth, and presence/absence of *Macrocystis* and/or *Nereocystis* kelp (discussed below) as the most important and tractable factors that may influence the distribution and abundance of murres and murrelets. Our surveying effort of the nearshore coastal waters of Washington in summer 1996 occurred from 21 May through 15 August, comprising 94 transects totaling 3984 kilometers (Tables 1-2). The location and timing of these surveys were designed to measure the influence of these variables on the distribution and abundance of murres and murrelets. In addition, these surveys served to replicate much of the work we did in the summer of 1995 (Tables 3-4) and winter of 1995-1996 (Tables 5-6) in order to (1) further improve and refine our survey methodology, and (2) see if our summer 1996 data would agree or disagree with data from our previous seasons, i.e. to determine the robustness of our previous results.

Methods and Statistical Analyses

Each "record" in our database includes, among other data, the species of bird observed, the number of birds observed in each observation (record), latitude, longitude, water depth and distance from shore, the latter two derived from GIS databases (overlays). Our survey effort is not uniform across all distances from shore or water depths; it also varies geographically (e.g. Strait of Juan de Fuca vs. northern or southern outer coast). If group size (number of birds observed in each observation) varies with distance from shore, then analyses of observations in relation to distance from shore may yield different results than analyses of total birds (observations weighted by group size) in relation to distance from shore (or water depth). Fortunately, group size does not appear to vary with distance from shore in murres or murrelets in winter or in summer (figures 14-18, two-way ANOVAs, $P \geq 0.215$). However, mean group size did vary between broad geographic regions in summer 1996 (but not winter 1995-1996); in murrelets, group size was smallest along the southern outer coast, larger along the northern outer coast, and largest along the Strait of Juan de Fuca (discussed below). Murres exhibited exactly the opposite pattern (discussed below). However, since most statistical analyses are confined to single broad geographic regions, differences in group size among regions do not affect most analyses. Thus most analyses were conducted on total birds observed (observations weighted by group size) rather than on unweighted bird observations.

Results

Group size. Distribution of group sizes of murres and murrelets is an indicator of the extent to which these species are distributed uniformly versus patchily in the environment. This is relevant to restoration because the more patchily a bird is distributed, (1) the more difficult it is to survey for them, (2) the more variable are survey data collected of them, (3), the more effort must be spent to collect sufficient data to address questions of concern, and (4) the more problematic are such survey data to analyze statistically. Murrelets and murres represent nearly opposite ends of the spectrum in this regard (figures 19-28). In both summer and winter, the large majority of murrelets are observed singly or in pairs, and very rarely congregate in groups of more than four or five. Murres also are most commonly observed singly or in small groups; however, they also congregate in large flocks such that the total number of murres in large flocks (e.g., more than 20 birds) typically exceeds the total number of birds observed in singly or in small groups. This is especially true in winter when nearly half of all murres are found in groups of at least 100 birds (figure 22). Thus, murres are much less uniformly distributed than are murrelets.

In addition, as mentioned above, group size appears to be positively correlated with overall population abundance in both murrelets (figures 23-25) and murres (figures 26-28).

Distance from shore and time of day. To determine the potential influence of time of day and distance to shore on the distribution and abundance of murres and murrelets, we conducted replicate transects at 200, 400, 800, and 1200 meters from shore in both the morning and afternoon in the summer of 1996 (as well as in summer 1995 and winter 1995-1996). Various nonparametric (Friedmann, Kruskal-Wallis and Mann-Whitney U tests, Spearman rank correlations) and parametric analyses (two-way ANOVAs followed by post-hoc tests, and linear regression analyses) of these data indicate that in both summer and winter the density of murrelets decreases significantly with both time of day and distance from shore (figures 1-6), distance from shore being a stronger effect than time of day. In contrast, the distribution and abundance of murres was not significantly related to time of day or distance from shore ($P > 0.2$ in all cases, and usually greater than 0.5).

Using a GIS database of the Washington shoreline, we determined the distance from shore of each bird observation in the winter of 1995-1996 and summer of 1996. The distribution of distances from shore of murrelet observations corroborates the results from our transect data above, the highest densities being at 200 meters to 400 meters from shore (figures 29-30). In contrast to our negative results regarding murres above, the distribution of distances from shore of murre observations showed a surprisingly marked result in both winter and summer: Murres appear to be strongly concentrated at 1000 meters to 2500 meters offshore (figures 31-32). Surprisingly, however, murre distribution is not correlated with water depth as one might expect (discussed below).

The idea of conducting so-called zig-zag transects instead of parallel transects has been suggested by some biologists and discussed at various seabird meetings. To empirically determine whether zig-zag and parallel transects yield similar results, we conducted zig-zag transects between 100 meters and 1300 meters offshore in the same area in which we conducted the parallel transects discussed above. In a zig-zag transect, effort is distributed approximately uniformly across all distances from shore within the width of distances being surveyed. Thus, the mean density of birds observed in a zig-zag transect should approximate the mean density observed on all parallel transects (200M, 400M, 800M, and 1200M), averaged together. However, zig-zag transects appear to yield much lower densities of Marbled Murrelets (figure 33), although with our small sample size the difference was not significant (t-tests, P=0.241). Why this would be the case is not entirely clear. For murres, however, zig-zag transects appear to estimate their abundance as well as parallel transects (figure 34), and because zig-zag transects cover a greater range of distances from shore, they are less subject to potential biases than are parallel transects.

Water depth. Using a GIS database of the bathymetry (water depth) of the Washington coast (Port Angeles west to Tatoosh Island, south to and including the Columbia River), we determined the water depth of each bird observation in the winter of 1995-1996 and summer of 1996. Because depth is correlated with distance from shore, it is not surprising that murrelets are more abundant in shallow than in deep water. In the summer of 1995, murrelets were found most often in water 9-12 meters deep (figure 35); however, these data are not corrected for variation in effort at different water depths, and, thus may be biased. In the winter of 1995-1996, murrelets were most common at about the same depth (11-15 M, figure 36); however, in the summer of 1996, they were most common in shallower water (1-5 meters, figure 37). The results from winter 1995-1996 and summer 1996 are corrected for differences in effort at different water depths and, therefore, are not potentially biased.

Using depth sounder data, we also compared the depths at which adult versus juvenile Marbled Murrelets were observed in summer 1996, and found that adults and juveniles appear to be distributed in a very similar fashion to one another with respect to water depth (figure 38). In contrast to murrelets, the distribution of murres does not appear to be influenced by water depth (figures 39-40), despite their apparent concentration at 1000 meters to 2500 meters offshore (discussed above).

The accuracy of the GIS bathymetry database was checked by taking depth measurements (from the depth sounders on our various research vessels) each time a murrelet was observed, and then comparing these data to the depths obtained from the GIS bathymetry database for the same latitude and longitude coordinates. Depth sounders are located on the bottom of the hulls of the research vessels we used and, therefore, are about three feet underwater. To correct for this, three feet was added to each depth sounding measurement. Regression analyses indicate that depth sounder data predict 83.8% of the variation in depth determined from GIS data (figure 41). Correlation analyses yield similar results. Despite the relatively good agreement between the GIS data and depth sounder data, the GIS data differ absolutely (i.e. both positively and negatively) by an average (± SD) of 4.1 ± 3.8 meters or an average of 26.8 ± 20.9% in winter 1995-1996 (figure 42) to 2.5 ± 2.8 meters or an average of 22.2 ± 16.6% in summer 1996 (figure 43), with a mean difference of 2.8 ± 4.8 meters in winter 1995-1996 (figure 42) to 1.9 ± 3.3 meters in summer 1996 (figure 43).

Why the GIS data are consistently less than depth sounder data by an average of 2.5 to 4.1 meters is a mystery. The GIS database we use is an abridged form of NOAA's bathymetry database in which all NOAA data within 100 meter x 100 meter blocks are averaged so that any bird observation within that block receives the same depth reading. We are currently upgrading our GIS database by reducing the block size to between 10 meters and 30 meters squared, i.e. an increase in resolution of 10 to 100 fold. In addition, the latitude and longitude coordinates used to derive depths from the GIS database were obtained from non-differential GPS's. In the future, we will use differential GPS's whenever possible. These improvements should vastly increase the accuracy of the GIS depth data so that sounder depth data and GIS depth data agree more closely in the future.

Task 4

From 13 through 15 August, we conducted transects between Port Angeles and Sekui to estimate the ratio of juvenile to adult murrelets as an index of murrelet reproductive success. Juveniles comprised 17.18% (50/291) of murrelets observed. This is a higher percentage than has ever been observed in any surveys of juvenile murrelet abundance in Washington (or elsewhere to my knowledge). However, it is interesting to note that 70% of murrelets recovered from the *Tenyo Maru* oil spill were juveniles. This apparent anomaly has yet to be explained or understood. This high percentage could have resulted from one or more of the following reasons: (1) our surveys were accurate, i.e. the actual percentage of juveniles in 1996 was about 17%; (2) juveniles and/or adults did not distribute themselves in the same fashion during the post-breeding season resulting in high concentrations of juveniles in the areas we surveyed, e.g., patchy distribution of juveniles was observed by Dave Nysewander (WDFW) in Puget Sound in 1995; (3) this could reflect a bias on the part of myself and my crew toward identifying some adults (e.g. those molting into winter [definitive basic] plumage) as juveniles.

Implications for Restoration

Repeatable and statistically valid sampling methods are essential in the analysis of distribution of seabirds. If *Tenyo Maru* restoration activities are to include an at-sea component, in terms of either monitoring changes in abundance, distribution, or habitat use, or relating seabird recovery to fish abundance and distribution, valid methods for counting and monitoring seabirds along the outer coast of Washington need to be tested and established. We have progressed a long way toward developing methods specifically designed for counting murres and murrelets (discussed above). We anticipate that our future research will allow us to further improve and refine these methods into a protocol suitable for (1) long-term at-sea censusing of murres and murrelets in Washington state, and (2) analyses of distribution and abundance data collected by these methods. We suggest that all future at-sea sseabird surveys associated with *Tenyo Maru* restoration should follow these protocols, regardless of whether the work conducted by a trustee agency or by other public or private organizations.

Our results indicate that murrelets are most numerous early in the morning and close to shore. In contrast, murre densities do not change in relation to time of day, and appear to be concentrated further from shore (primarily between 1000 meters and 2500 meters from shore). Because of these differences between murres and murrelets, it is not possible to survey optimally for both species with the same methodology, e.g., at the same distance from shore. Since murrelets are more densely concentrated in the morning, a logistically and fiscally reasonable way to survey for these species would be to survey for murrelets close to shore in the morning, and for murres further from shore in the afternoon. Also, because zig-zag transects appear to yield lower (and more variable) densities of murrelets, we recommend continuing to use parallel rather than zig-zag transects for murrelets. For murres, however, zig-zag transects are probably superior because the wide range of distances (e.g., 1000M to 2500M) from shore that could be covered by such transects reduce the probability of missing large concentrations of murres at different distances from shore that might be missed by one or more transects parallel to shore.

Our results indicate that murrelets do prefer habitats that contain kelp versus those that do not. However, we do not know why murrelets prefer habitats with kelp. Thus, additional studies of kelp communities and the activities of murrelets in areas with and without kelp are warranted

Future Plans

Our data from the winter of 1996-1997 have not yet been analyzed, but they will be prior to winter 1997-1998, sooner if time permits. As I mentioned above, using ECI's software as well as WDFW GIS capabilities, we will overlay our abundance and distribution data for murres and murrelets on GIS databases of the distribution and abundance of old growth forest and shoreline/substrate structure when these become available.

In addition, it has been suggested that juvenile murrelets prefer to stay in or near kelp more so than do adults. Thus, we will address this through analyses of our data collected during (1) general sampling, (2) sampling designed specifically to look at possible habitat preference by adults or juveniles for kelp, and (3) adult/juvenile ratio sampling.

Our data have addressed many of the original tasks identified. However, four serious and related methodological issues remain. First, although we collected preliminary data regarding the utility of parallel vs. zig-zag transects for counting murres and murrelets, our sample sizes were small in 1996. Thus, additional evaluation of these alternative methods is warranted.

The second issue regards between-season and between-year variability in densities of murres and murrelets. We know from past research that numbers of seabirds, including murres and murrelets, are tremendously variable in time and space. This is unfortunate because their inherent variability makes detecting meaningful changes in population levels of these birds very difficult, e.g., in the short-term (within as much as a few years), apparent increases or decreases in population levels may simply reflect variability in numbers of birds breeding, or migrating/dispersing, but not total numbers of birds in a "population." To detect real population changes, these birds must be monitored over many years in order to measure within- and between-year variability in their numbers, and thereby discriminate short-term fluctuations in apparent population numbers from long-term real changes in population numbers.

The third issue, implied above, regards statistical power. We now know when and where to survey for murres and murrelets (discussed above); however, from a management perspective, one of our primary goals is to be able to monitor population trends, and to use these trends as indices of the success or failure of various *Tenyo Maru* restoration activities. To do so, it is necessary to know how many replicates of a given survey/transect should be done, on average, in order to achieve the statistical power required to detect a change of a given magnitude over a specified time interval. The number of replicates necessary is proportional to the variability of the data; the more variable the data, the more replicates are necessary. Thus, we plan to do a large number of replicate transects within and between months in summer and winter 1997 along the Strait of Juan de Fuca and northern outer coast to collect data on variability in order to generate a "power curve" that will indicate the relationship between magnitude of population change over a given time period and statistical power. Ideally, the *Tenyo Maru* Restoration Plan will specify the minimum magnitude of change in population levels of murres and murrelets that they want to be able to detect, and the time interval over which they want to detect it.

The fourth issue regards a possible transect methodology that could improve our statistical power. To date we have used "strip" transects; in this method, all birds are counted within a "strip" of 100 meters on each side of our boat. This method has two basic errors: (1) observers must be able to accurate estimate the distance of 100 meters from the boat in order to accurately determine which birds are inside versus outside the "strip," and (2) the detectability of birds in relation to distance from the boat differs among transects due to differences in observers, weather (sun, glare, cloud cover, wind, rain), sea conditions (swell height and period, wind waves, etc.), and platform (i.e., boat height, size, etc.). An alternative transect method is the "line" transect (Buckland et al. 1993). This method is very similar to the strip transect method, but differs in a few critical ways. In a line transect, like a strip transect, birds are counted only within a specified distance on each side of a boat; however, in a line transect, the perpendicular distance to each bird from the boat is also estimated and recorded. By doing so, a detecability curve of the percentage of observations as a function of distance from the boat may be generated. From this, one may empirically determine the percentage of birds being missed on any given transect or set of transects. In turn, this may be used to "correct" transects to reflect the total number of birds that would have been seen if all birds had been detected. By largely eliminating differences in the detectability between transects, this method has the potential to vastly reduce variability in our data, thereby increasing our statistical power. However, the accuracy of this method relies on two critical assumptions being met: (1) all birds must be detected that are "close" (i.e., within about 30 meters) to the transect line of the boat, and (2) the boat must not cause birds to dive or move away from the transect line before being detected. If either of these assumptions are seriously violated, then subsequent analyses of line transect data will yield erroneous results. Thus, we plan to conduct transects in the summer of 1997 to empirically measure the relative magnitude of errors involved in strip vs. line transects.

Objective 2: At-sea surveys of Marbled Murrelet use of areas with and without kelp

Progress to Date

Integrating remote sensing and GIS data with distribution and abundance data collected at sea has already proven to be valuable as described above (i.e., with bathymetry and distance from shore data). Similarly, we found that Washington Department of Natural Resources' (DNR) GIS database of the distribution of *Nereocystis* and *Macrocystis* kelp on the Washington coast was very useful for determining whether the distribution of murres and/or murrelets is influenced by presence/absence of kelp. Overlaying DNR's kelp GIS database with our distribution and abundance data for murres and murrelets indicates that in both winter and summer murrelets are found much more often near kelp, and much less often far away from kelp, than expected by chance (figures 44-46, Kolmogorov-Smirnov tests, $P<0.0001$). In contrast, murres are distributed in the opposite fashion, i.e. they are found much more often far away from kelp than expected by chance (figures 47-48, Kolmogorov-Smirnov tests, $P<0.0001$). In the near future, we hope to do similar analyses using a two other GIS databases currently under development (one of shoreline physical structure, and the other of old growth forest distribution [currently being editing and improved through groundtruthing]).

In addition to the GIS analysis, we identified areas on the outer coast and the Strait of Juan de Fuca with and without kelp that otherwise appear to be physically similar. We conducted focal observations of seabirds in these areas to determine the feasibility of this technique for observing numbers and behaviors of seabirds. If found to be feasible, we would use this technique to quantify use of areas with and without kelp by murrelets.

Unfortunately, we found this technique to be of no value for murrelets or any other seabirds. In short, the approach of our boat to a focal area scared away all birds immediately or within a few minutes at the longest. Even at anchor with our engines off, birds failed to return to within 100 meters of our boat within an hour. Thus, it is my opinion that this approach is not suitable for conducting seabird count or behavioral observations.

Implications for Restoration

Focal observations at sea of bird behavior in relation to habitat type (e.g., kelp) is not practical, and should not be pursued in the future. The GIS kelp analysis presented above clearly documents that murrelets prefer areas with kelp. The question remains, why do they prefer areas with kelp, and how can we collect data to answer that question. My opinion is that land-based surveys of areas with high concentrations of kelp and murrelets along the Strait of Juan de Fuca (e.g., Freshwater Bay) is most likely to be the most cost-effective way to address this question.

Future Plans

I do not currently have any plans to conduct land-based surveys of areas with and without kelp. To do so would require an additional employee and additional equipment (e.g., a Questar telescope). I do not have monies to fund such an undertaking, but it could be done if the *Tenyo Maru* Trustee's Council decided to fund such a project.

Objective 3: Use of Refuge islands by Common Murres for breeding

Specific tasks funded:

(1) document possible breeding of murres on Point Grenville complex
(2) conduct rectilinear grids around breeding colonies and non-breeding "control" sites.

Progress to Date

Task 1

Historically, murres are known to have bred on many rocks and islands along the outer Washington coast south of Tatoosh Island. However, in the last decade or so, Tatoosh Island is the only location at which murres are well documented to currently breed annually. Ulrich Wilson (unpubl. data) has observed chicks recently on various other colonies (e.g., Huntingdon Island in 1995) on which murres are known to have bred previously. If accurate, these data clearly indicate that murres are breeding in at least small numbers at some other locations in Washington. Nevertheless, better documentation, and estimates of numbers of breeding pairs are necessary.

Prior to the summer 1996 field season, we planned to monitor potential breeding colonies (e.g. Grenville Arch) from both land and sea. We envisioned the at-sea data collection as involving two basic goals. The first goal was to estimate the numbers of murres seen on colonies and document their behaviors (movements to and from colony, food carrying behavior, presence of eggs, chicks, courtship behavior etc.). To do so, however, we needed to get permission from the Quinaults to observe the Grenville complex, and Split and Willoughby Rocks, and from the Quilleutes to observe the Quilleute Needles. In addition, we also needed a high-powered telescope (e.g., Questar or equivalent) to observe birds at these sites which are approximately 1000 meters or more from shore. The *Tenyo Maru* Trustee's Council did not fund the equipment that we requested in 1996. In addition, however, by 25 June we had received numerous reports from biologists in Oregon and Washington that murres were either not returning to breeding colonies to attempt to breed or that those that were already on colonies were deserting en masse. As a result, we decided not to expend *Tenyo Maru* funds trying to monitor breeding activity at potential breeding colonies on the outer coast (e.g. Grenville Arch) because collecting negative data regarding absence of breeding murres at these sites in a potentially poor year would not substantially address the issue.

Our second goal was to quantify the distribution and abundance of murres around potential breeding colonies with the hope that patterns discerned from these data might be used as potential indicators of breeding activity. In order for this latter component to be useful, it is first necessary to document the pattern of distribution and abundance of murres around known active colonies as well as non-breeding sites as "controls" against which to compare murre distribution patterns around potential breeding colonies. To determine the pattern of distribution of murres around Tatoosh Island (i.e., the largest known active breeding colony in Washington) and a non-breeding "control" site (centered at 48.2495 N, 124.7790W) about 10 miles south of Tatoosh Island, we conducted rectilinear transects around both sites. Each transect was composed of five parallel legs (about 8.5 km long) oriented east to west and separated from one another by about two km. Four replicates of each transect were conducted in both the morning and afternoon at each site.

Our analyses (two-way ANOVA's followed by post-hoc tests) regarding Tatoosh Island indicate that, within the area around Tatoosh Island that we surveyed (mainly ≤ 5 km), murres were significantly more numerous within one km of the colony than at any other distance (figure 49), the densities beyond four km being very low. Thus, although the size of our rectilinear grid was chosen somewhat arbitrarily *a priori*, it fortuitously appears to have been a good choice in that surveying at distances beyond 4-5 km are probably unlikely to yield very meaningful data. This conclusion is corroborated by data collected by Julia Parrish (Parrish pers. comm.); she conducted two rectilinear grid transects around Tatoosh Island in 1995, one grid of similar size and location to ours, and a much larger grid extending more than 20 km from Tatoosh Island. In her small grid, she found a distribution of murres around Tatoosh similar to the distribution we found, and also found that densities of murres in her large grid (> 5 km from Tatoosh) were lower than those in the outermost distances of her small grid (≤ 5 km from Tatoosh). We also found that densities were higher in the morning than in the afternoon, although this difference was not significant ($P = 0.168$), probably due to our small sample sizes.

Not surprisingly, our results regarding the "control" site showed no pattern of distribution of murres with respect to distance from the center of the grid (analogous to Tatoosh Island) or time of day (figure 50).

Implications for Restoration

If rectilinear grids are to be used as one of many potential criteria to help determine whether murres are breeding at Washington localities other than Tatoosh Island, they should be conducted in the morning, and should encompass all waters within four to five km of each potential breeding site. What is not clear is how the density distribution of murres would differ around a site being attended by, but not bred on, by murres compared to an actual breeding site. The density distributions may not differ. However, if the density distributions do differ significantly from one another, then this survey method may be a useful criterion for determining breeding status. And the only way to determine this is to do it.

Future Plans

Individual murre breeding colonies vary in their phenology as well as their relative attendance and reproductive success. This variation presumably reflects both local and regional differences among colonies, especially with regard to prey availability. With regard to potential breeding colonies in Washington (e.g., Grenville complex, Quilleute Needles), it is unknown whether they tend to more closely follow the phenology of Oregon or Washington colonies. Data on murre attendance and behavior at potential breeding colonies in Washington would be very useful in this regard. Thus, we plan to do in summer 1997 what we had planned to do in the summer of 1996, i.e., to conduct (1) land-based surveys of the Grenville complex for possible breeding activity, (2) at-sea rectilinear grids around the localities at which murres are most likely to be breeding based on Ulrich Wilson's aerial flight data (K. Warheit and U. Wilson, pers. comm.), i.e., the Grenville Arch complex and Quilleute Needles, and (3) at-sea estimates of numbers of birds attending these localities, and note any observations or behaviors that may be indicative of breeding, e.g., food-carrying, presence of chicks, courtship behavior etc. We are in the process of discussing the logistics of doing this with both the Quinaults and Quilleutes.

Table 1. Number of surveys conducted at sea of portions of the Strait of Juan de Fuca and outer coast of Washington in relation to time of day and distance from shore during the summer of 1996.

	Morning					Afternoon				
Location	200 M	400 M	800 M	1200 M	Zig-Zag	200 M	400 M	800 M	1200 M	Zig-Zag
Port Angeles-Sekui	1	1	1	1		1	1	1	1	
Sekui - Neah Bay		2	2	2	3	1	2	2	2	3
Neah Bay - Cape Alava		2		3			1		2	
Cape Alava - Lapush		1		2			1		1	
Lapush - Hoh Head		1		1						
Hoh Head - Pt. Grenville		1		1					1	
Pt. Grenville - Gray's Harbor		1		1					1	
Gray's Harbor - Willapa Bay		2		2						
Willapa Bay - Columbia River		3		2			1		4	
Columbia River *			17 km					26 km		
Gray's Harbor *			134 km					273 km		
Willapa Bay *			118 km					59 km		

* Surveying these areas with transects parallel to shore is not possible because of limitations imposed by bathymetric, tidal, and sea state conditions. Thus, areas were surveyed as comprehensively as possible in an opportunistic fashion given these limitations.

Table 2. Chronology and description of transects conducted by WDFW on the Strait of Juan de Fuca and outer Coast of Washington during the summer of 1996.

Survey Date	Transect Location. Description. and Time	Kilometers	Number of Marbled Murrelets observed	Number of Common Murres observed	Density of Marbled Murrelets per sq. km	Density of Common Murres per sq. km
21 May	Tatoosh AM no 1 grid	29.67	0.00	198.00	0.00	33.37
21 May	Control PM no. 1 grid	42.95	3.00	222.00	0.35	25.84
23 May	Zig-Zag AM. Neah Bay to Sekui	18.14	21.00	46.00	5.79	12.68
23 May	1200 Meter AM. Neah Bay to Sekui	15.07	3.00	40.00	1.00	13.27
23 May	400 Meter AM, Neah Bay to Sekui	13.95	3.00	19.00	1.08	6.81
23 May	800 Meter AM. Neah Bay to Sekui	14.29	5.00	6.00	1.75	2.10
23 May	1200 Meter PM. Neah Bay to Sekui	14.98	2.00	9.00	0.67	3.00
23 May	400 Meter PM. Neah Bay to Sekui	14.08	9.00	23.00	3.20	8.17
23 May	800 Meter PM. Neah Bay to Sekui	14.28	7.00	9.00	2.45	3.15
23 May	Zig-Zag PM. Neah Bay to Sekui	18.32	5.00	8.00	1.36	2.18
24 May	Control Grid AM no. 1	61.89	2.00	802.00	0.16	64.79
24 May	Tatoosh Grid PM no. 1	30.94	6.00	125.00	0.97	20.20
29 May	Gray's Harbor. 50% am. 50% pm	122.65	12.00	875.00	0.49	35.67
30 May	Gray's Harbor mid-channel pm	29.65	6.00	41.00	1.01	6.91
30 May	Gray's Harbor AM	10.89	0.00	0.00	0.00	0.00
30 May	Grays Harbor to Willapa Bay (offshore*) AM	37.91	14.00	163.00	1.85	21.50
30 May	Gray's Harbor to Willapa Bay (nearshore**) AM	54.91	12.00	221.00	1.09	20.12
31 May	Willapa Bay to Columbia River (nearshore) AM	53.53	2.00	842.00	0.19	78.65
31 May	Willapa Bay to Columbia River (offshore) AM/PM	67.74	0.00	844.00	0.00	62.30
11june	Pt. Grenville - Hoh Head (offshore PM)	57.80	23.00	21.00	1.99	1.82
11 June	Pt. Grenville - Gray's Harbor (offshore PM)	43.46	2.00	110.00	0.23	12.66
11 June	Pt. Grenville - Hoh Head (nearshore AM)	59.35	17.00	18.00	1.43	1.52
12 June	Gray's Harbor to Pt. Grenville (offshore AM)	39.18	10.00	31.00	1.28	3.96
13 June	Willapa Bay; 2/3 AM, 1/3 PM	79.68	13.00	14.00	0.82	0.88
14 June	Willapa Bay AM	55.27	1.00	2.00	0.09	0.18
18 June	Cape Alava - Lapush (offshore) PM	37.24	34.00	804.00	4.57	107.95
18 June	Hoh Head - Cape Alava (offshore) AM	20.55	4.00	147.00	0.97	35.77
18 June	Lapush - Cape Alava (nearshore) AM	40.73	8.00	263.00	0.98	32.29
18 June	Lapush - Hoh Head (nearshore) AM	22.23	4.00	68.00	0.90	15.29
19 June	search for kelp patches	252.73	1.00	0.00	0.02	0.00
20 June	Lapush N to C. Alava (offshore) AM	51.32	14.00	384.00	1.36	37.41
21 June	Lapush N to Cape Alava (nearshore) PM	32.82	56.00	200.00	8.53	30.47
25 June	Cape Alava N to Neah Bay (nearshore) PM	42.17	30.00	621.00	3.56	73.63
25 June	Control Grid PM no. 2	36.93	0.00	162.00	0.00	21.93
25 June	Tatoosh Grid AM no. 2	35.39	3.00	734.00	0.42	103.70
26 June	Control Grid PM no. 3	43.83	1.00	122.00	0.11	13.92
26 June	Neah Bay S to Cape Alava (nearshore) AM	44.28	37.00	631.00	4.18	71.25
26 June	Tatoosh Grid PM no. 2	30.47	0.00	358.00	0.00	58.75
27 June	Cape Alava N to Neah Bay (offshore) PM	47.13	0.00	919.00	0.00	97.50
27 June	Neah Bay S to Cape Alava (offshore) AM	44.68	1.00	644.00	0.11	72.07
27june	20 Fathom depth contour AM	25.55	5.00	94.00	0.98	18.40
01 July	Columbia River E to Astoria and back (PM)	26.25	0.00	720.00	0.00	137.14
01 July	Leadbetter Pt. S to Columbia R. (nearshore AM)	82.30	0.00	2542.00	0.00	154.44
01 July	Columbia R. part way N to leadbetter Pt., offshore PM	69.89	12.00	1863.00	0.86	133.28
02 July	Columbia R. N to Leadbetter point (offshore) PM	64.88	4.00	1437.00	0.31	110.74
02 July	Leadbetter Pt. S to Columbia R. (offshore) AM	67.70	7.00	4447.00	0.52	328.43
02 July	Columbia River (to Astoria)	17.12	1.00	7.00	0.29	2.04
03 July	Willapa Bay between Green can and Yellow buoy, AM	7.97	2.00	67.00	1.25	42.03
10 July	Cape Alava N to Neah Bay (offshore) AM	45.04	3.00	344.00	0.33	38.19
10 July	Neah Bay S to Cape Alava (nearshore) AM	46.54	42.00	721.00	4.51	77.46
10 July	Tatoosh grid PM no. 3	28.91	0.00	155.00	0.00	26.81

Table 2. (Continued) Chronology and description of transects conducted by WDFW on the Strait of Juan de Fuca and outer Coast of Washington during the summer of 1996.

Survey Date	Transect Location, Description, and Time	Kilometers	Number of Marbled Murrelets observed	Number of Common Murres observed	Density of Marbled Murrelets per sq. km	Density of Common Murres per sq. km
11 July	Control Grid AM no. 2	50.05	0.00	365.00	0.00	36.46
11 July	Tatoosh grid AM no. 3	30.49	1.00	301.00	0.16	49.36
16 July	Columbia R. N to Leadbetter Pt. (nearshore) PM	65.17	3.00	757.00	0.23	58.08
16 July	Leadbetter Pt. to Columbia R. (offshore) AM	75.96	5.00	1335.00	0.33	87.88
16 July	Willapa Bay, Green can to yellow Buoy PM	8.04	0.00	234.00	0.00	145.52
23 July	Tatoosh Grid AM no. 4	29.81	0.00	92.00	0.00	15.43
23 July	Cape Alava N to Neah Bay (offshore PM)	44.83	0.00	422.00	0.00	47.07
23 July	Neah Bay S to Cape Alava (nearshore PM)	24.46	3.00	114.00	0.61	23.30
24 July	Sail Rock to Kydaka Pt., Zig-zag AM	17.67	1.00	17.00	0.28	4.81
24 July	Sail Rock to Kydaka Pt., 1200 METER PM	15.03	0.00	12.00	0.00	3.99
24 July	Sail Rock to Kydaka Pt., 400 METER PM	13.79	2.00	8.00	0.73	2.90
24 July	Sail Rock to Kydaka Pt., ZIG-ZAG PM	17.86	0.00	14.00	0.00	3.92
24 July	Sail Rock to Kydaka Pt., 800 METER PM	14.24	0.00	18.00	0.00	6.32
25 July	Sail Rock to Kydaka Pt., 400 M AM	14.24	4.00	30.00	1.40	10.53
25 July	Sail Rock to Kydaka Pt., 200 M AM	11.59	18.00	62.00	7.77	26.75
25 July	Sail Rock to Kydaka Pt., 800 M AM	14.32	1.00	12.00	0.35	4.19
25 July	Sail Rock to Kydaka Pt., 1200 M AM	15.00	0.00	16.00	0.00	5.33
25 July	Sail Rock to Kydaka Pt., ZIG-ZAG AM	18.00	7.00	18.00	1.94	5.00
25 July	Sail Rock to Kydaka Pt., ZIG-ZAG PM	17.88	3.00	33.00	0.84	9.23
26 July	Control Grid AM no. 3	67.28	0.00	181.00	0.00	13.45
26 July	Sail Rock to Kydaka Pt., 200 M PM	13.20	13.00	16.00	4.92	6.06
30 July	Columbia R. N to Leadbetter Pt (offshore) PM	61.21	0.00	1614.00	0.00	131.84
30 July	Leadbetter Pt. to Columbia R. (nearshore) AM	66.61	3.00	4395.00	0.23	329.91
31 July	Gray's Harbor S to Willapa Bay (nearshore) AM	34.16	3.00	107.00	0.44	15.66
31 July	Gray's Harbor N to Pt. Grenville (nearshore) AM	46.83	38.00	1150.00	4.06	122.78
31 July	Pt. Grenville S to Gray's Harbor (offshore) PM	49.61	7.00	533.00	0.71	53.72
31 July	Willapa Bay N to Gray's Harbor (offshore) AM	33.88	14.00	117.00	2.07	17.27
01 August	Pt. Grenville N to Hoh Head (offshore) AM	127.02	90.00	541.00	3.54	21.30
06 August	Port Angeles to Sekui (200 M) AM	80.13	446.00	54.00	27.83	3.37
06 August	Sekui to Port Angeles (400 M) PM	81.34	346.00	84.00	21.27	5.16
07 August	Port Angeles to Sekui (400 M) AM	82.61	459.00	295.00	27.78	17.86
07 August	Sekui to Port Angeles (200 M) PM	81.46	346.00	58.00	21.24	3.56
08 August	Port Angeles to Sekui (800 M) AM	82.43	128.00	227.00	7.76	13.77
08 August	Sekui to Port Angeles (1200 M) PM	79.98	3.00	387.00	0.19	24.19
09 August	Low Pt. east to Port Angeles (1/2 transect; 800 M) PM	41.22	52.00	330.00	6.31	40.03
09 August	Port Angeles to low Pt. (1/2 transect; 1200 M) AM	42.71	9.00	227.00	1.05	26.57
13 August	200 Meter Adult:juvenile ratio AM	37.94	309.00		40.72	0.00
13 August	500 M adult:juvenile ratio PM	30.29	19.00		3.14	0.00
14 August	800 M adult:juvenile ratio AM	49.68	206.00		20.73	0.00
14 August	200 M adult:juvenile ratio PM	18.83	137.00		36.38	0.00
15 August	adult-juvenile ratio	12.85	81.00		31.52	0.00
	* "offshore" = 1200 meters — Total Km =	3984.93				
	** "nearshore" = 400 meters — Total miles =	2490.58				

Table 3. Number of surveys conducted at sea of portions of the Strait of Juan de Fuca and outer coast of Washington in relation to time of day and distance from shore during the summer of 1995.

	Morning					Afternoon				
Location	200 M	400 M	800 M	1200 M	10 & 20 Fathom	200 M	400 M	800 M	1200 M	10 & 20 Fathom
Port Angeles-Sekui										
Sekui - Neah Bay	2	2	2	2	2 ea.	4	4	3	1	2 ea.
Neah Bay - Cape Alava		2		2			2		2	
Cape Alava - Lapush				1			1			
Lapush - Hoh Head				1			1			
Hoh Head - Pt. Grenville		1		1			1		1	
Pt. Grenville - Gray's Harbor		1		2			1		1	
Gray's Harbor - Willapa Bay		1		1			1		1	
Willapa Bay - Columbia River		2		2			1		1	
Columbia River *			None					None		
Gray's Harbor *			30 km					30 km		
Willapa Bay *			75 km					75 km		

* Surveying these areas with transects parallel to shore is not possible because of limitations imposed by bathymetric, tidal, and sea state conditions. Thus, areas were surveyed as comprehensively as possible in an opportunistic fashion given these limitations.

Table 4. Chronology and description of transects conducted by WDFW on the Strait of Juan de Fuca and outer coast of Washington during the summer of 1995

Survey Date	Transect Location, Description, and Time	Kilometers	Number of Marbled Murrelets observed	Density of Marbled Murrelets per sq. km
31 July	Sekui to Neah Bay, AM (no specific distance)	39.47	28	3.55
31 July	Neah Bay to Tatoosh Island, AM	13.19	0	0.00
31 July	Tatoosh Island to Sekui, PM	50.21	19	1.89
1 August	Neah Bay to Pillar Point, 1200 meters, AM	42.18	1	0.12
1 August	Neah Bay to Pillar Point, 800 meters, AM	41.64	4	0.48
1 August	Neah Bay to Pillar Point, 400 meters, PM	42.21	14	1.66
1 August	Neah Bay to Pillar Point, 200 meters, AM	49.08	23	2.34
2 August	Neah Bay to Pillar Point, 200 meters, AM	16.43	12	3.65
2 August	Neah Bay to Pillar Point, 800 meters, PM	43.08	1	0.12
8 August	Neah Bay to Hole in the Wall, 200 meters, PM	29.2	6	1.03
8 August	Neah Bay to Tatoosh Island, 400 meters, PM	13.89	3	1.08
9 August	Neah Bay to Sekui, 200 meters, AM	35.35	40	5.66
9 August	Neah Bay to Sekui, 1200 meters, AM	28.77	0	0.00
9 August	Neah Bay to Sekui, 800 meters, PM	30.99	5	0.81
9 August	Neah Bay to Sekui, 400 meters, PM	34.21	40	5.85
9 August	Sekui to Pillar Point, 200 meters, PM	12.78	3	1.17
9 August	Sekui to Pillar Point, 400 meters, PM	12.59	0	0.00
10 August	Neah Bay to Sekui, 400 meters, AM	31.54	19	3.01
10 August	Neah Bay to Sekui, 200 meters, AM	32.94	17	2.58
10 August	Neah Bay to Sekui, 200 meters, PM	34.64	27	3.90
10 August	Neah Bay to Sekui, 800 meters, PM	29.4	0	0.00
10 August	Neah Bay to Sekui, 1200 meters, PM	29.34	0	0.00
11 August	Neah Bay to Sekui, 800 meters, AM	17.72	7	1.98
11 August	Neah Bay to Sekui, 400 meters, AM	56.29	28	2.49
20 August	Tatoosh Island to Cape Alava, 10 fathom, PM	16.32	0	0.00
20 August	Tatoosh Island to Cape Alava, 400 meters, PM	26.24	11	2.10
21 August	Tatoosh Island to Cape Alava, 10 fathoms, AM	28.72	2	0.35
21 August	Tatoosh Island to Cape Alava, 400 meters, PM	26.05	12	2.30
21 August	Tatoosh Island to Cape Alava, 20 fathoms, PM	26.03	0	0.00
21 August	Tatoosh Island to Cape Alava, 10 fathoms, PM	24.49	4	0.82
22 August	Tatoosh Island to Cape Alava, 10 fathoms, AM	22.4	0	0.00
22 August	Tatoosh Island to Cape Alava, 400 meters, AM	26.73	20	3.74
22 August	Tatoosh Island to Cape Alava, 20 fathoms, PM	26.67	0	0.00
22 August	Tatoosh Island to Cape Alava, 1200 meters, PM	25.89	0	0.00
23 August	Tatoosh Island to Cape Alava, 400 meters, AM	26.9	19	3.53
23 August	Tatoosh Island to Cape Alava, 20 fathoms, AM	29.98	0	0.00
23 August	Tatoosh Island to Cape Alava, 1200 meters, AM	26.05	0	0.00
23 August	Tatoosh Island to Cape Alava, 1200 meters, PM	25.88	0	0.00
24 August	Tatoosh Island to Cape Alava, 1200 meters, AM	28.79	0	0.00
24 August	Tatoosh Island to Cape Alava, 20 fathoms, AM	31.78	0	0.00
4 September	Grenville Arch to Hoh Head, 400 meters, AM	61.93	32	2.58

Table 4. (Continued) Chronology and description of transects conducted by WDFW on the Strait of Juan de Fuca and outer coast of Washington during the summer of 1995.

Survey Date	Transect Location, Description, and Time	Kilometers	Number of Marbled Murrelets observed	Density of Marbled Murrelets per sq. km
4 September	Grenville Arch to Hoh Head, 1200 meters, PM	58.05	2	0.17
5 September	Willapa Bay to Columbia River, 400 meters, AM	44.87	0	0.00
5 September	Willapa Bay to Columbia River, 1200 meters, PM	41.09	0	0.00
6 September	Gray's Harbor	59.61	1	0.08
10 September	Grenville Arch to Hoh Head, 1200 meters, AM	64.09	15	1.17
10 September	Grenville Arch to Hoh Head, 400 meters, PM	63.59	19	1.49
10 September	Gray's Harbor to Pt. Grenville, 400 meters, PM	45.84	9	0.98
11 September	Gray's Harbor to Willapa Bay, 400 meters, AM	17.1	0	0.00
11 September	Willapa Bay to Columbia River, 1200 meters, AM	48.33	0	0.00
11 September	Willapa Bay to Columbia River, 400 meters, AM	42.06	0	0.00
11 September	Gray's Harbor to Willapa Bay, 1200 meters, PM	21.34	0	0.00
11 September	Gray's Harbor to Willapa Bay, 1200 meters, PM	17.24	0	0.00
12 September	Gray's Harbor to Pt. Grenville, 400 meters, AM	44.9	13	1.45
12 September	Gray's Harbor to Pt. Grenville, 1200 meters, AM	42.43	15	1.77
12 September	Gray's Harbor to Pt. Grenville, 1200 meters, PM	43.15	0	0.00
19 September	Willapa Bay	75.23	0	0.00
20 September	Willapa Bay	74.88	2	0.13

* "nearshore" = 400 meters — Total Km = 890.5

** "offshore" = 1200 meters — Total miles = 619.8

Table 5. Number of surveys conducted at sea of portions of the Strait of Juan de Fuca and outer coast of Washington in relation to time of day and distance from shore during the winter of 1995-1996.

	Morning				Afternoon			
Location	200 M	400 M	800 M	1200 M	200 M	400 M	800 M	1200 M
Port Angeles-Sekui								
Sekui - Neah Bay	2	2	2	0	2	2	2	0
Neah Bay - Cape Alava		1						
Cape Alava - Lapush				1		1		
Lapush - Hoh Head				1		1		
Hoh Head - Pt. Grenville						1		
Pt. Grenville - Gray's Harbor		1						1
Gray's Harbor - Willapa Bay		1						
Willapa Bay - Columbia River		Partial						
Columbia River *		None				None		
Gray's Harbor *		182 km				62 km		
Willapa Bay *		100 km				126 km		

* Surveying these areas with transects parallel to shore is not possible because of limitations imposed by bathymetric, tidal, and sea state conditions. Thus, areas were surveyed as comprehensively as possible in an opportunistic fashion given these limitations.

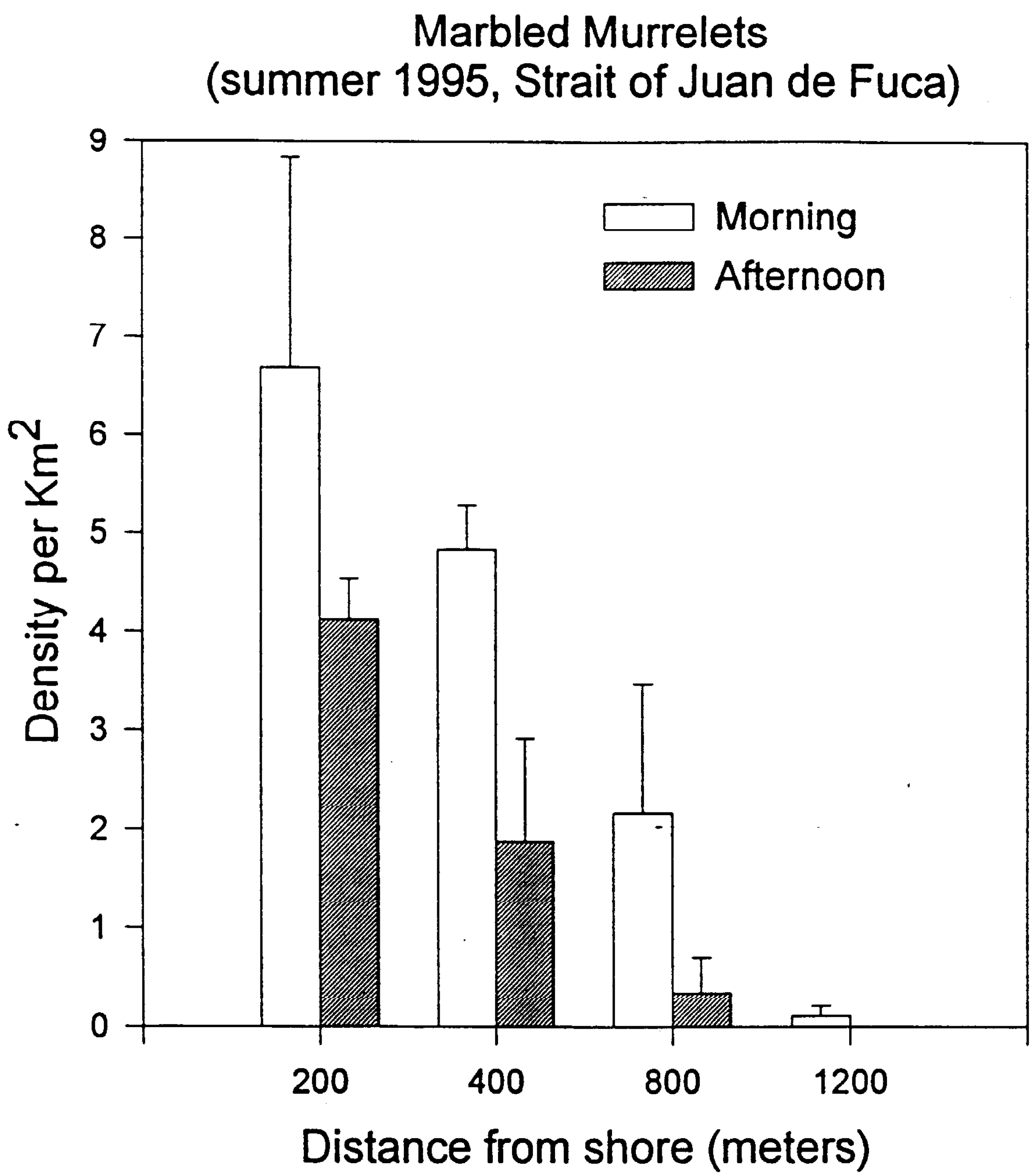
Table 6. Chronology and description of transects conducted by WDFW on the Strait of Juan de Fuca and outer Coast of Washington during the winter of 1995-1996.

Survey Date	Transect Location, Description, and Time	Kilometers	Number of Marbled Murrelets observed	Number of Common Murres observed	Density of Marbled Murrelets per sq. km	Density of Common Murres per sq. km
23 January	Willapa Bay PM	25.77	0.00	0.00	0.00	0.00
12 February	Gray's Harbor PM	109.51	4.00	0.00	0.18	0.00
12 February	Gray's Harbor PM	3.11	0.00	0.00	0.00	0.00
13 February	Gray's Harbor AM	28.71	0.00	21.00	0.00	3.66
13 February	Gray's Harbor PM	48.86	0.00	0.00	0.00	0.00
14 February	Gray's Harbor AM	11.31	0.00	0.00	0.00	0.00
14 February	Gray's Harbor AM	1.24	0.00	0.00	0.00	0.00
14 February	Gray's Harbor 50%AM / 50% PM	40.97	11.00	0.00	1.34	0.00
12 March	Sekiu to Neah Bay, 400 Meter A.M.	29.83	5.00	48.00	0.84	8.05
12 March	Sekiu to Neah Bay, 200 Meter P.M.	31.51	7.00	0.00	1.11	0.00
12 March	Sekiu to Neah Bay, 400 Meter P.M.	27.00	7.00	21.00	1.30	3.89
12 March	Sekiu to Neah Bay, 800 Meter A.M.	28.08	0.00	85.00	0.00	15.14
13 March	Sekiu to Neah Bay, 200 Meter A.M.	32.40	33.00	4.00	5.09	0.62
13 March	Sekiu to Neah Bay, 200 Meter P.M.	31.55	21.00	0.00	3.33	0.00
13 March	Sekiu to Neah Bay, 400 Meter A.M.	26.48	16.00	7.00	3.02	1.32
13 March	Sekiu to Neah Bay, 800 Meter P.M.	27.54	1.00	11.00	0.18	2.00
14 March	Sekiu to Neah Bay, 200 Meter A.M.	31.69	40.00	0.00	6.31	0.00
14 March	Sekiu to Neah Bay, 400 Meter P.M.	29.42	11.00	0.00	1.87	0.00
14 March	Sekiu to Neah Bay, 800 Meter A.M.	26.40	0.00	117.00	0.00	22.16
14 March	Sekiu to Neah Bay, 800 Meter P.M.	26.32	5.00	16.00	0.95	3.04
14 March	Sekiu to Neah Bay, 200 Meter A.M., incomplete	12.91	0.00	0.00	0.00	0.00
21 March	Hoh Head to Cape Alava, nearshore* PM	58.61	2.00	4.00	0.17	0.34
22 March	Waadah Island to Cape Alava, nearshore AM	65.43	0.00	0.00	0.00	0.00
22 March	Hoh Head S to Pt. Grenville, nearshore PM	58.68	0.00	4.00	0.00	0.34
22 March	Cape Alava S to Hoh Head, offshore** AM	58.47	2.00	79.00	0.17	6.76
26 March	Gray's Harbor S to Willapa Bay, PM	37.74	20.00	0.00	2.65	0.00
26 March	Gray's Harbor N. to Pt. Grenville, nearshore AM	43.22	0.00	172.00	0.00	19.90
26 March	Pt. Grenville S. to Gray's Harbor, offshore PM	42.68	7.00	282.00	0.82	33.04
27 March	Willapa Bay to Columbia River (partial)	1.96	3.00	0.00	7.65	0.00

* "nearshore" = 400 meters — Total Km = 997.40

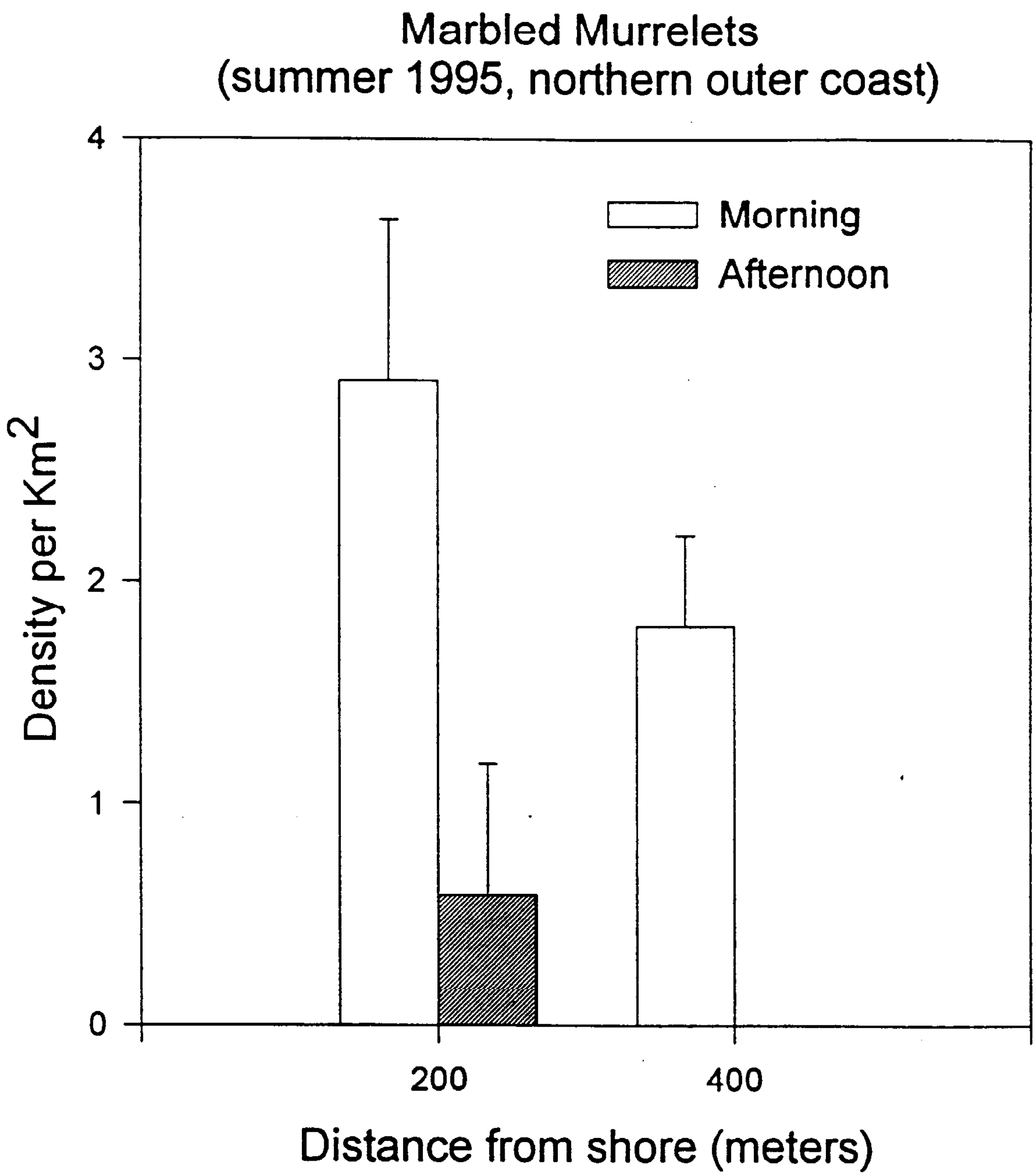
** "offshore" = 1200 meters — Total miles = 619.80

Figure 1



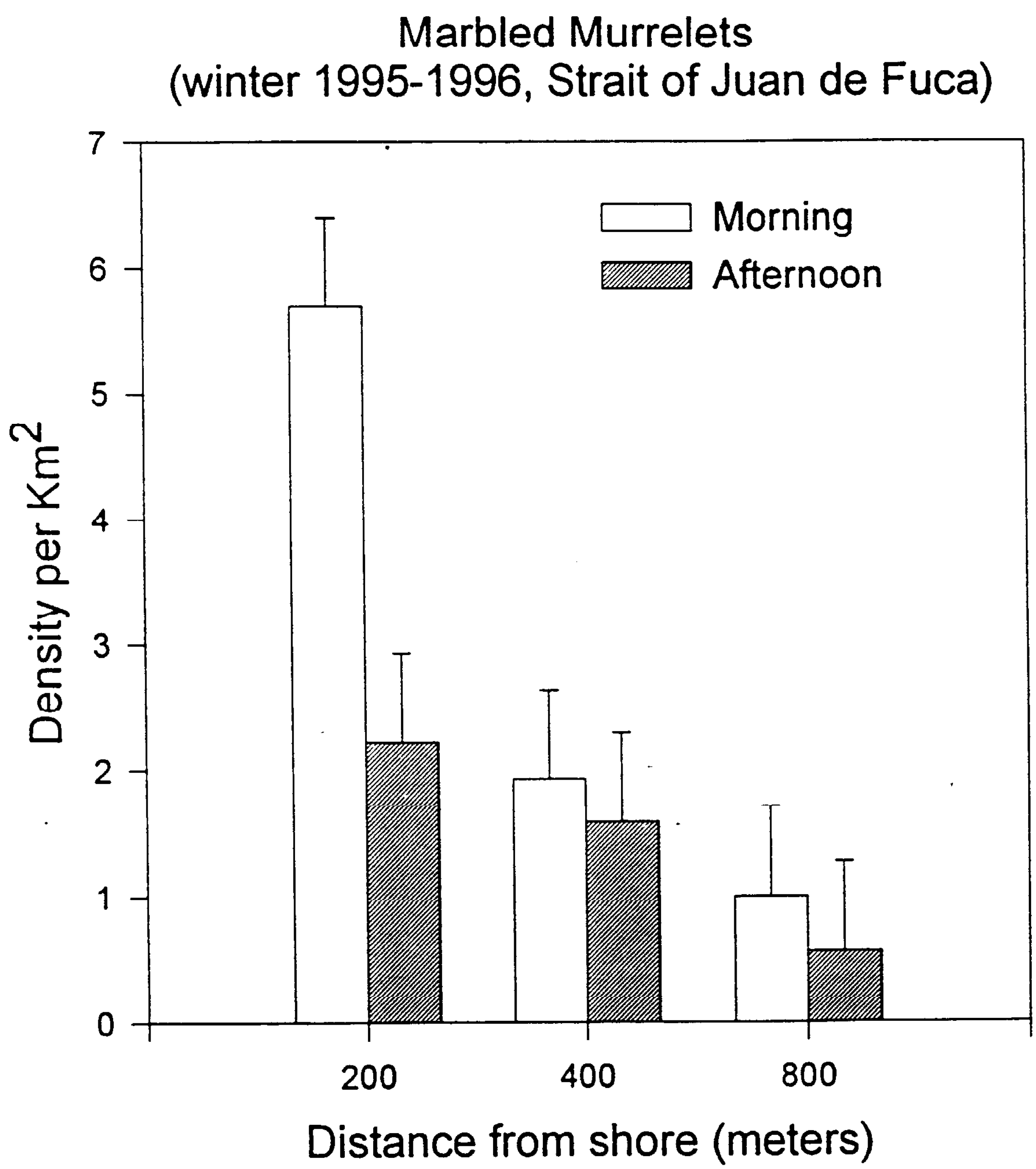
Marbled Murrelets
(summer 1995, Strait of Juan de Fuca)
Morning
Afternoon
Density per Km2
0
1
2
3
4
5
6
7
8
9
200
400
800
1200
Distance from shore (meters)

Figure 2



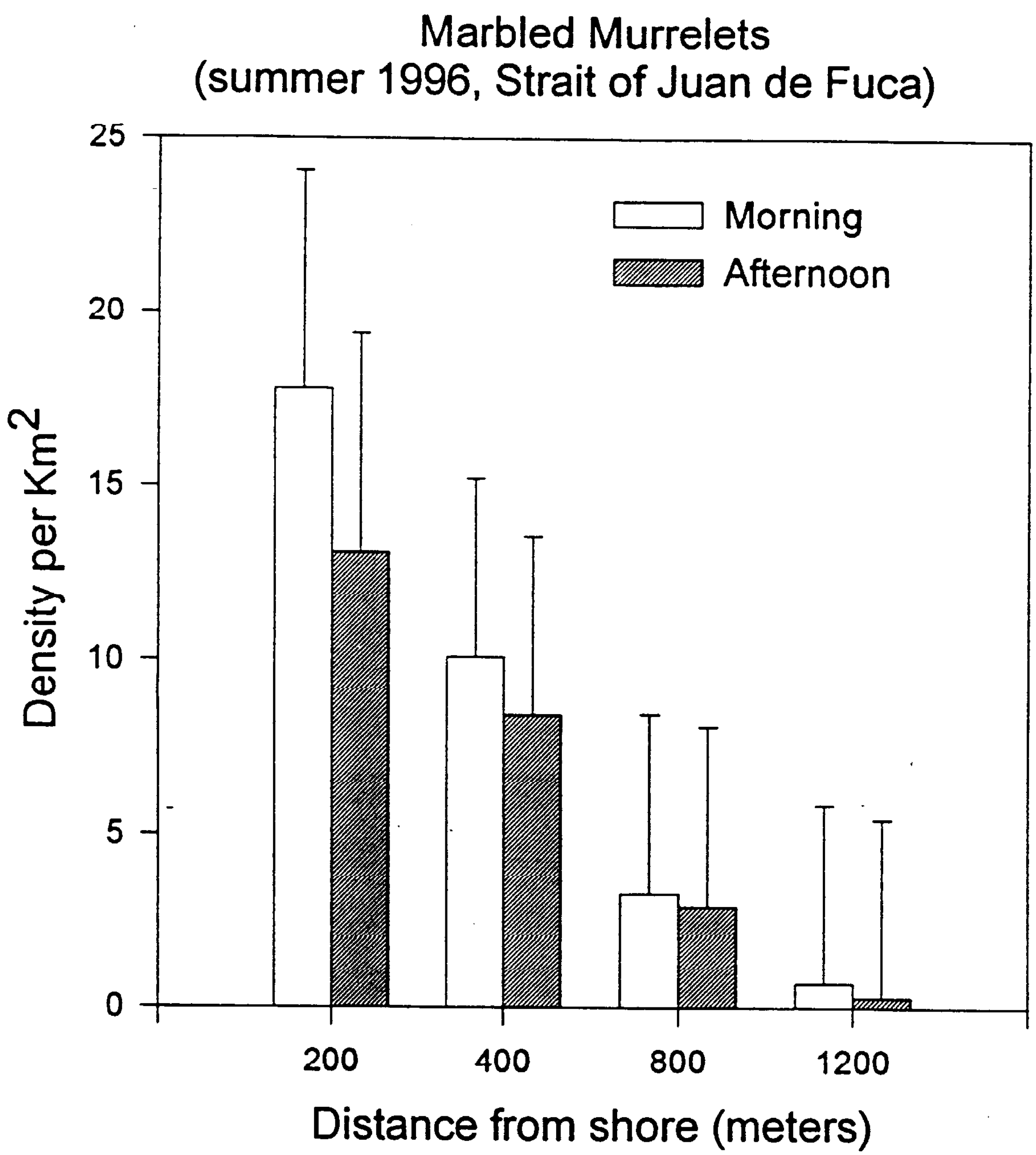
Marbled Murrelets
(summer 1995, northern outer coast)
Morning
Afternoon
Density per Km2
0
1
2
3
4
200
400
Distance from shore (meters)

Figure 3



Marbled Murrelets
(winter 1995-1996, Strait of Juan de Fuca)
Morning
Afternoon
Density per Km2
0
1
2
3
4
5
6
7
200
400
800
Distance from shore (meters)

Figure 4



Marbled Murrelets
(summer 1996, Strait of Juan de Fuca)
25
20
15
10
5
0
Density per Km2
Morning
Afternoon
200
400
800
1200
Distance from shore (meters)

Figure 5

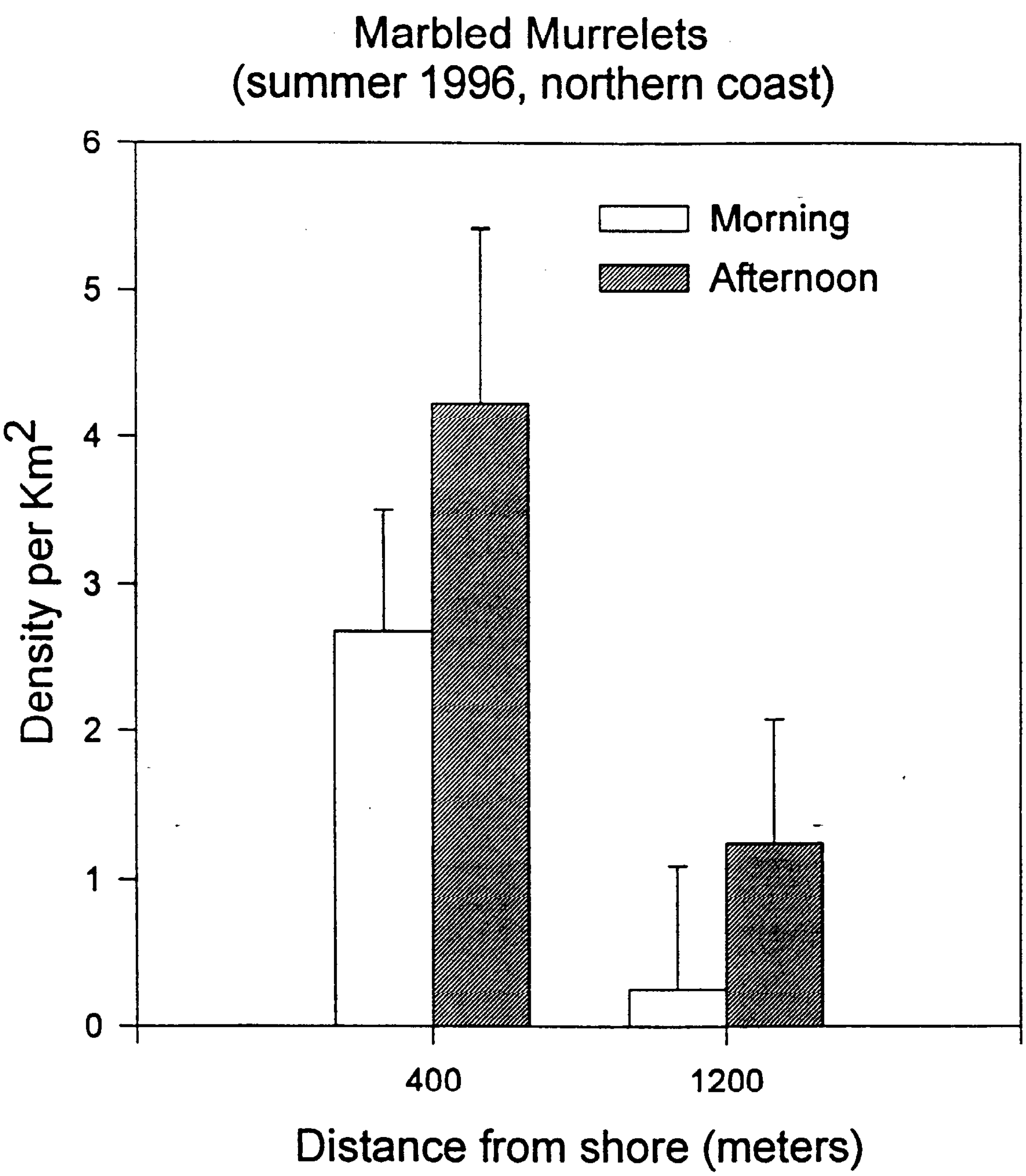

Marbled Murrelets
(summer 1996, northern coast)
Morning
Afternoon
Density per Km^2
0
1
2
3
4
5
6
400
1200
Distance from shore (meters)

Figure 6

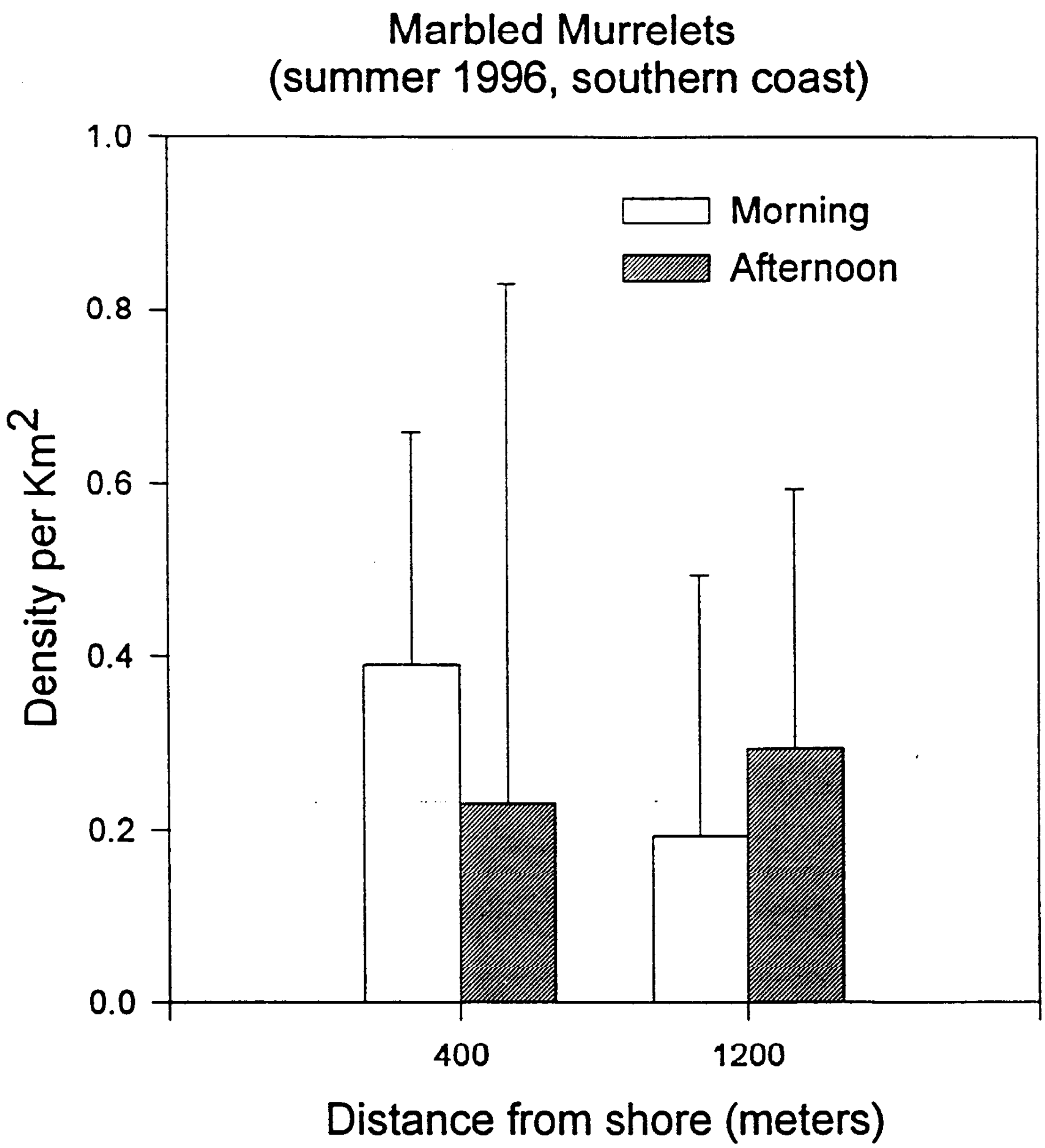
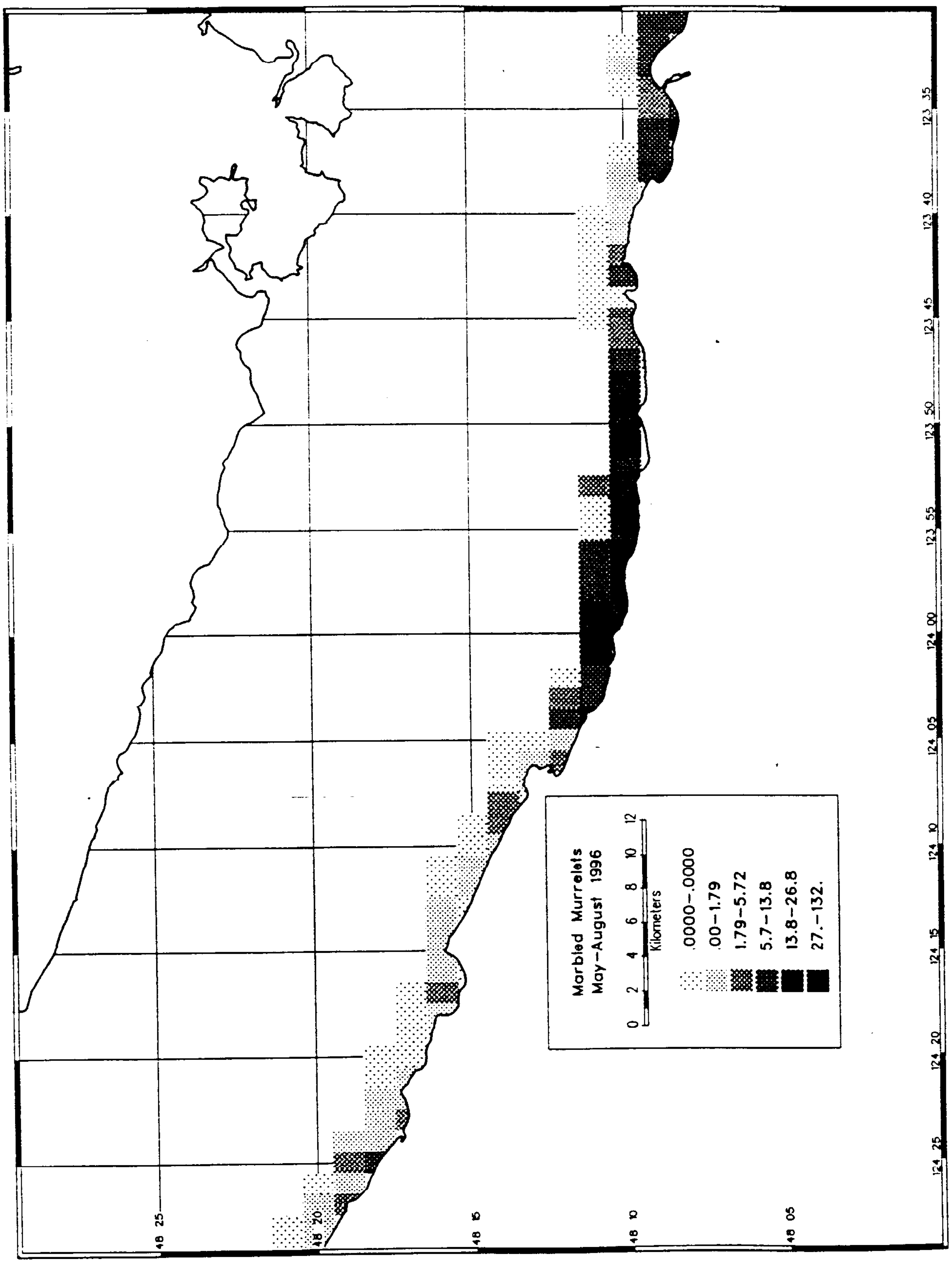

Marbled Murrelets
(summer 1996, southern coast)
Morning
Afternoon
Density per Km2
1.0
0.8
0.6
0.4
0.2
0.0
400
1200
Distance from shore (meters)

Figure 7a



Marbled Murrelets
May–August 1996
0 2 4 6 8 10 12
Kilometers
.0000–.0000
.00–1.79
1.79–5.72
5.7–13.8
13.8–26.8
27.–132.
48 25
48 20
48 15
48 10
48 05
124 25
124 20
124 15
124 10
124 05
124 00
123 55
123 50
123 45
123 40
123 35

Figure 7b

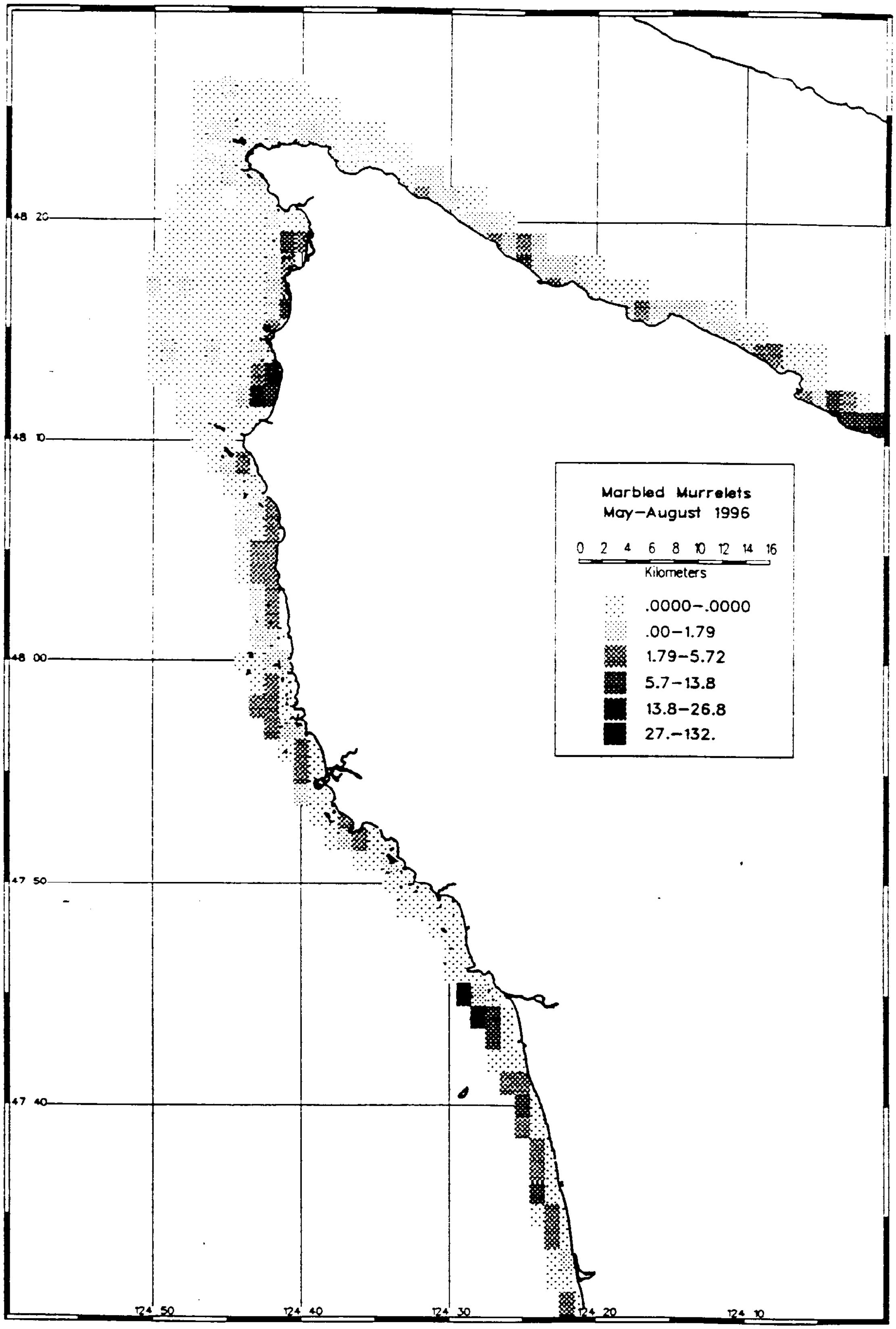

Marbled Murrelets
May–August 1996
0 2 4 6 8 10 12 14 16
Kilometers
.0000–.0000
.00–1.79
1.79–5.72
5.7–13.8
13.8–26.8
27.–132.
48 20
48 10
48 00
47 50
47 40
124 50
124 40
124 30
124 20
124 10

Figure 7c

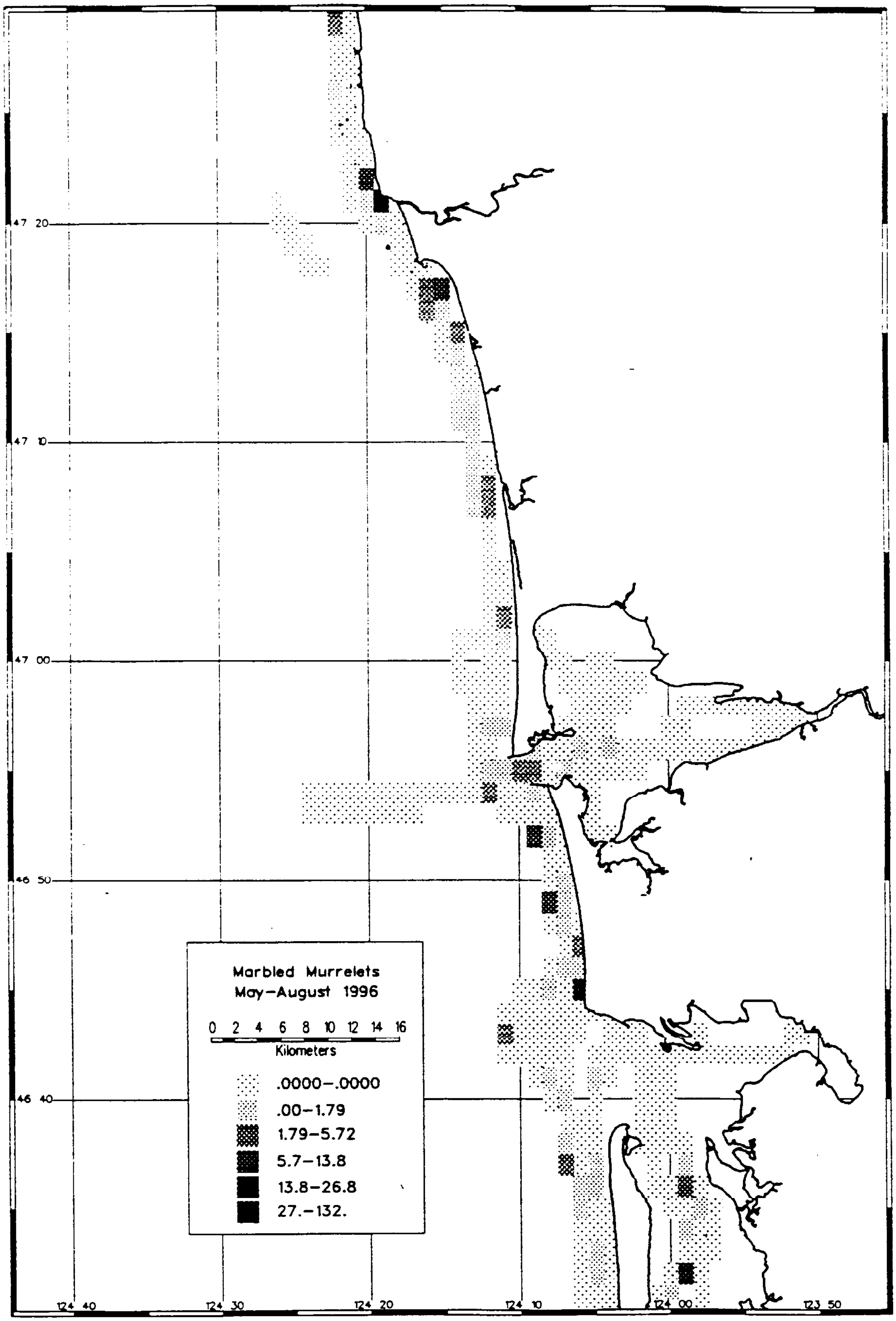

Marbled Murrelets
May-August 1996
0 2 4 6 8 10 12 14 16
Kilometers
.0000-.0000
.00-1.79
1.79-5.72
5.7-13.8
13.8-26.8
27.-132.
47 20
47 10
47 00
46 50
46 40
124 40
124 30
124 20
124 10
124 00
123 50

Figure 7d

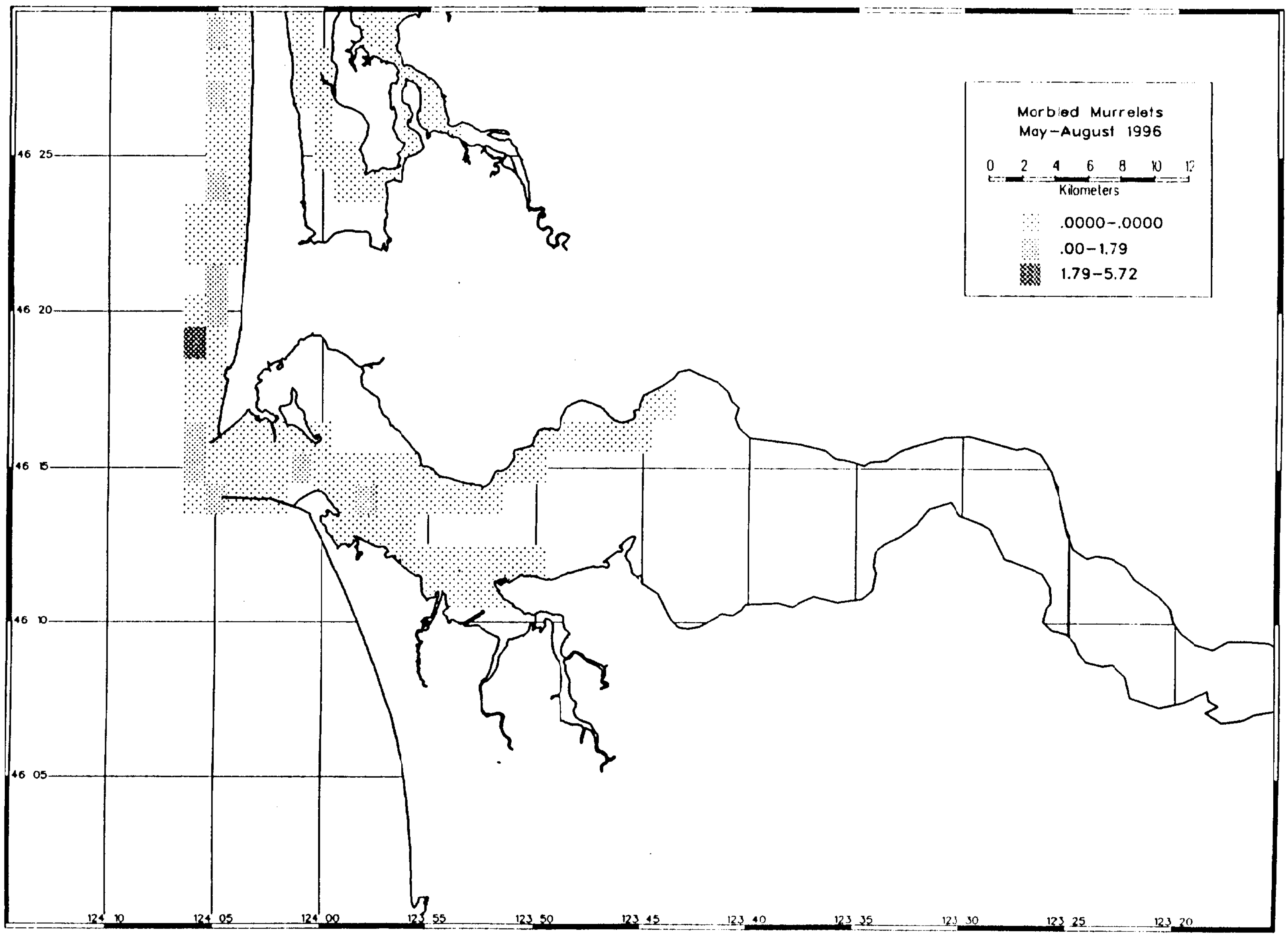

Morbled Murrelets
May-August 1996
0 2 4 6 8 10 12
Kilometers
.0000-.0000
.00-1.79
1.79-5.72
46 25
46 20
46 15
46 10
46 05
124 10
124 05
124 00
123 55
123 50
123 45
123 40
123 35
123 30
123 25
123 20

Figure 8a

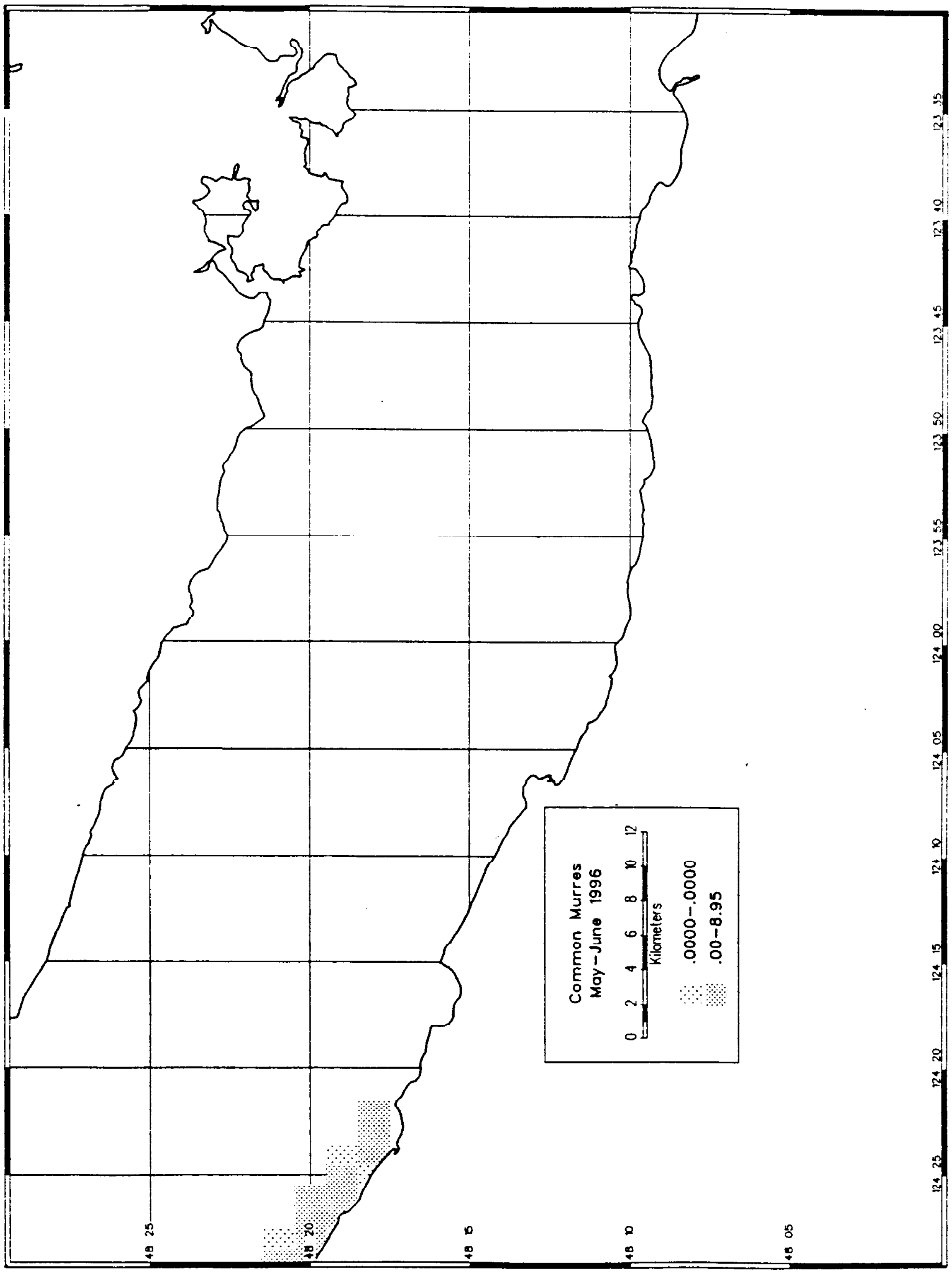
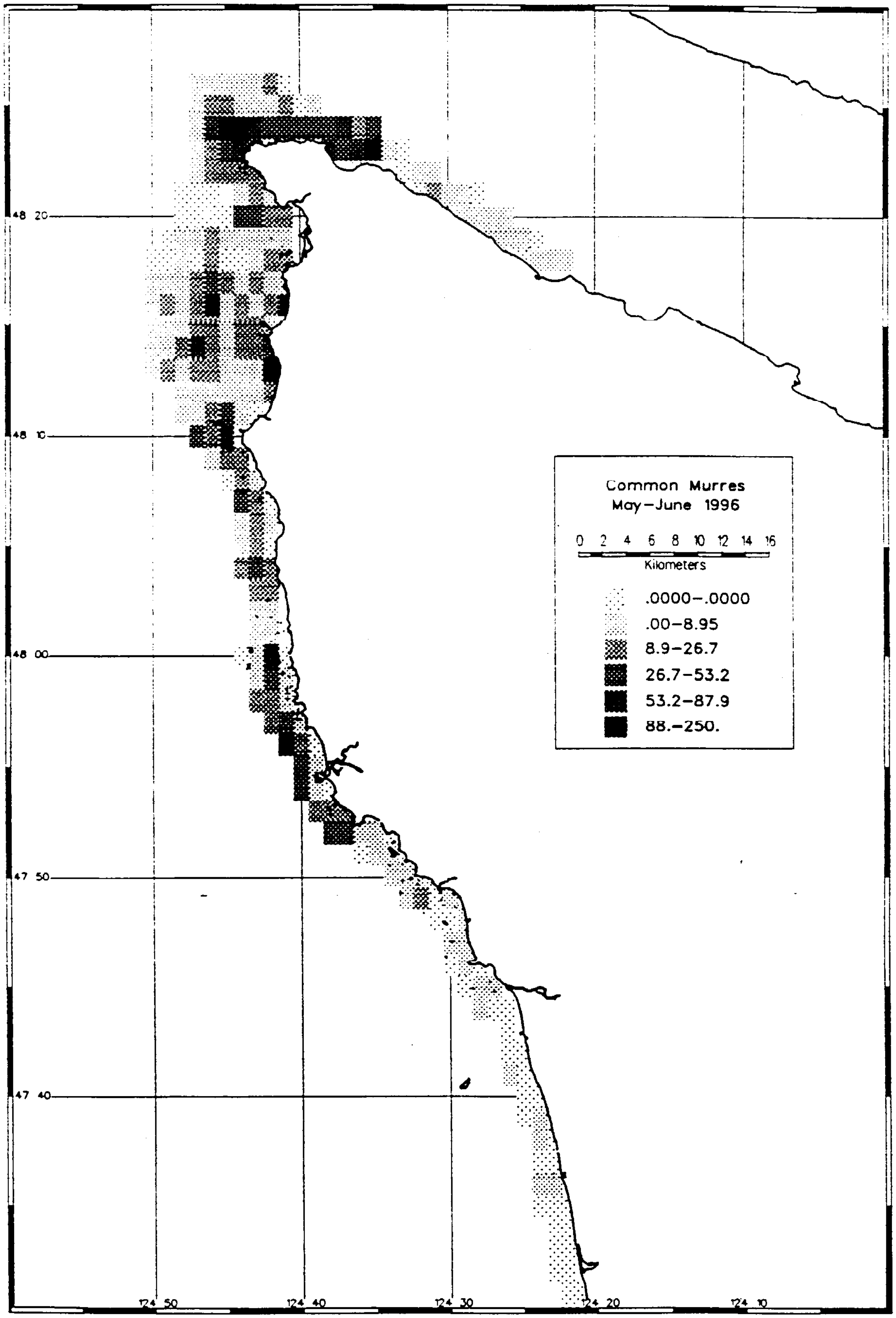
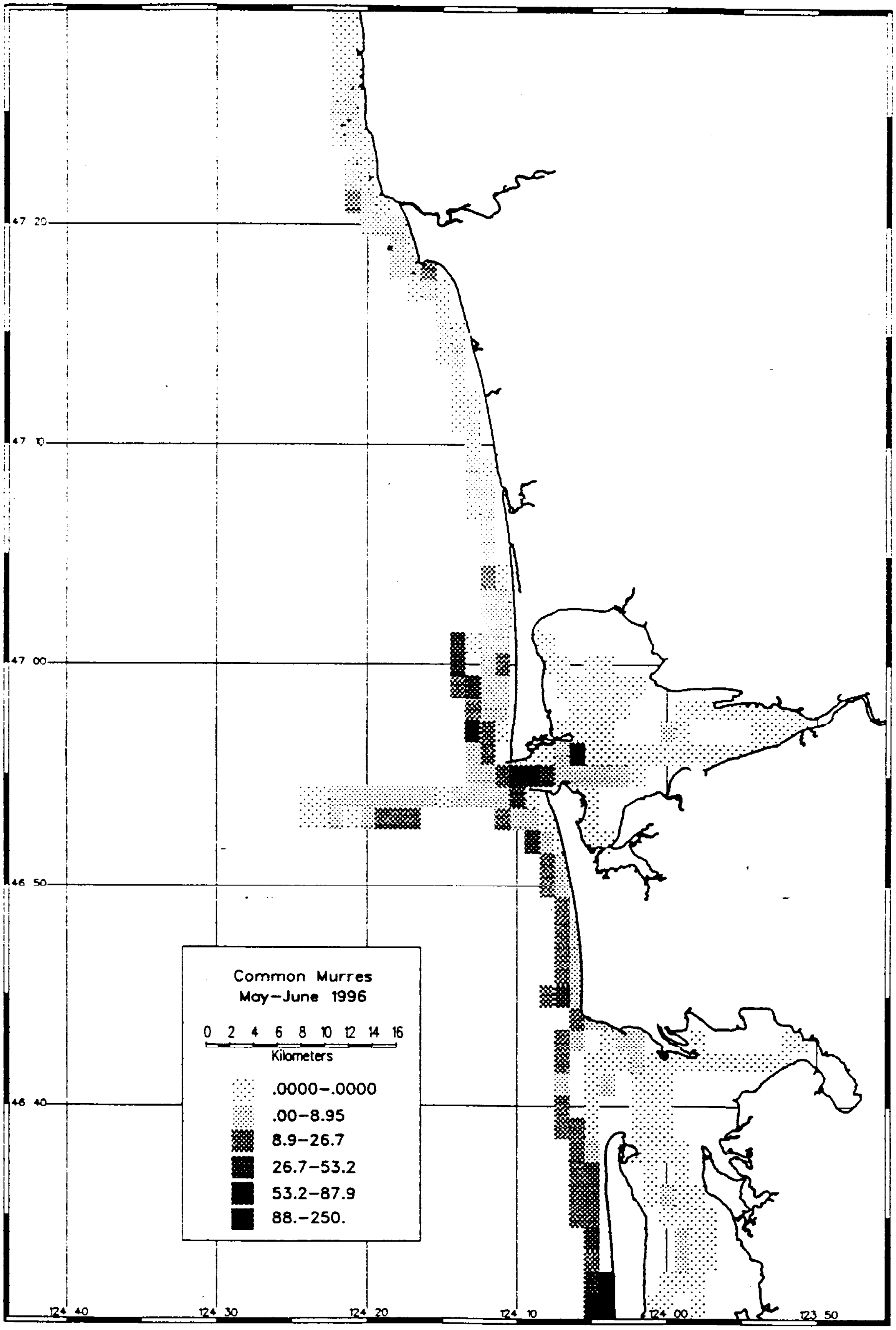

Common Murres
May-June 1996
0 2 4 6 8 10 12
Kilometers
.0000-.0000
.00-8.95
48 25
48 20
48 15
48 10
48 05
124 25
124 20
124 15
124 10
124 05
124 00
123 55
123 50
123 45
123 40
123 35

Figure 8b



Common Murres
May-June 1996
0 2 4 6 8 10 12 14 16
Kilometers
.0000-.0000
.00-8.95
8.9-26.7
26.7-53.2
53.2-87.9
88.-250.
48 20
48 10
48 00
47 50
47 40
124 50
124 40
124 30
124 20
124 10

Figure 8c



Common Murres
May–June 1996
0 2 4 6 8 10 12 14 16
Kilometers
.0000–.0000
.00–8.95
8.9–26.7
26.7–53.2
53.2–87.9
88.–250.
47 20
47 10
47 00
46 50
46 40
124 40
124 30
124 20
124 10
124 00
123 50

Figure 8d

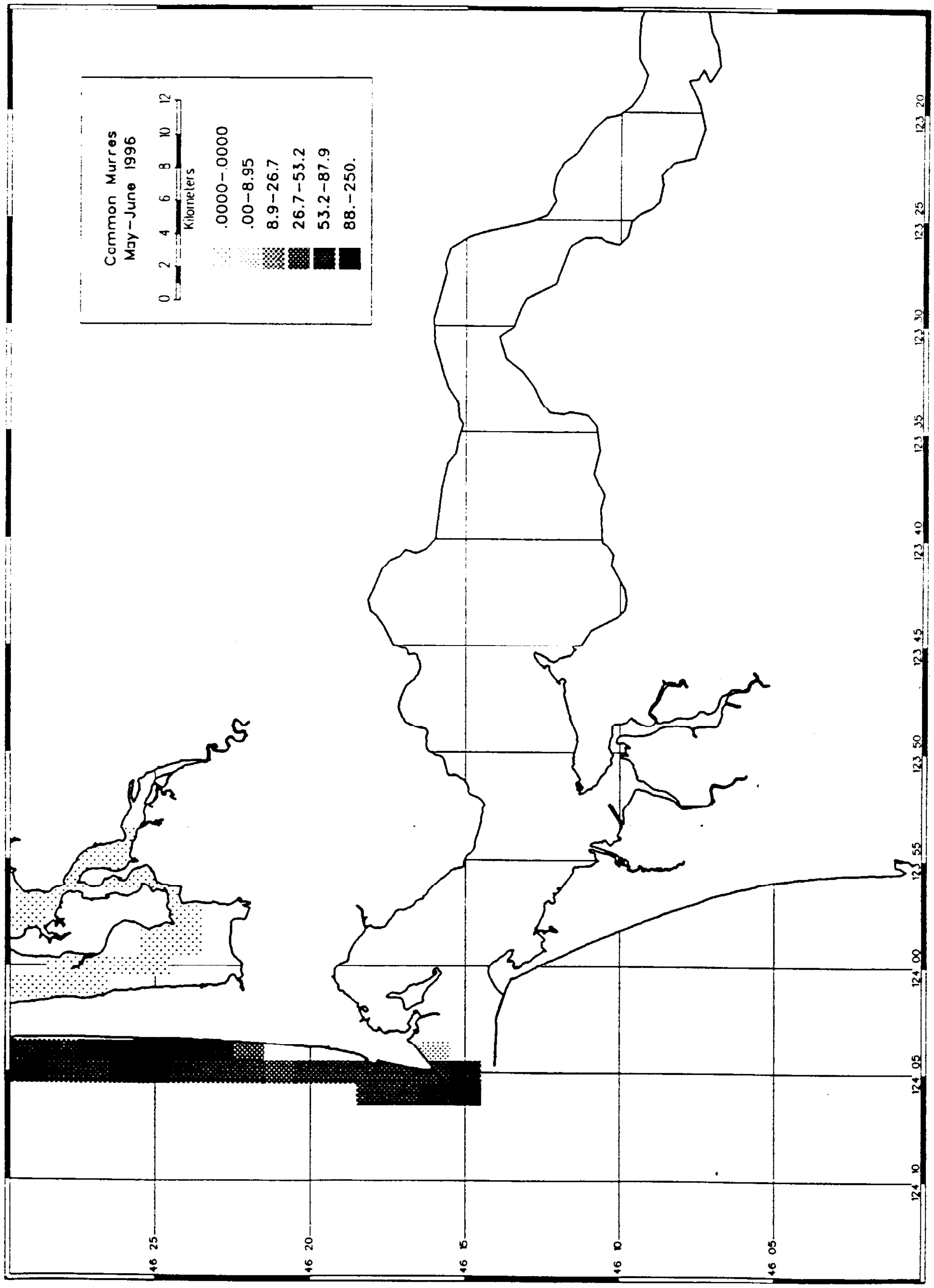

Common Murres
May-June 1996
0 2 4 6 8 10 12
Kilometers
.0000-.0000
.00-8.95
8.9-26.7
26.7-53.2
53.2-87.9
88.-250.
46 25
46 20
46 15
46 10
46 05
124 10
124 05
124 00
123 55
123 50
123 45
123 40
123 35
123 30
123 25
123 20

Figure 9a

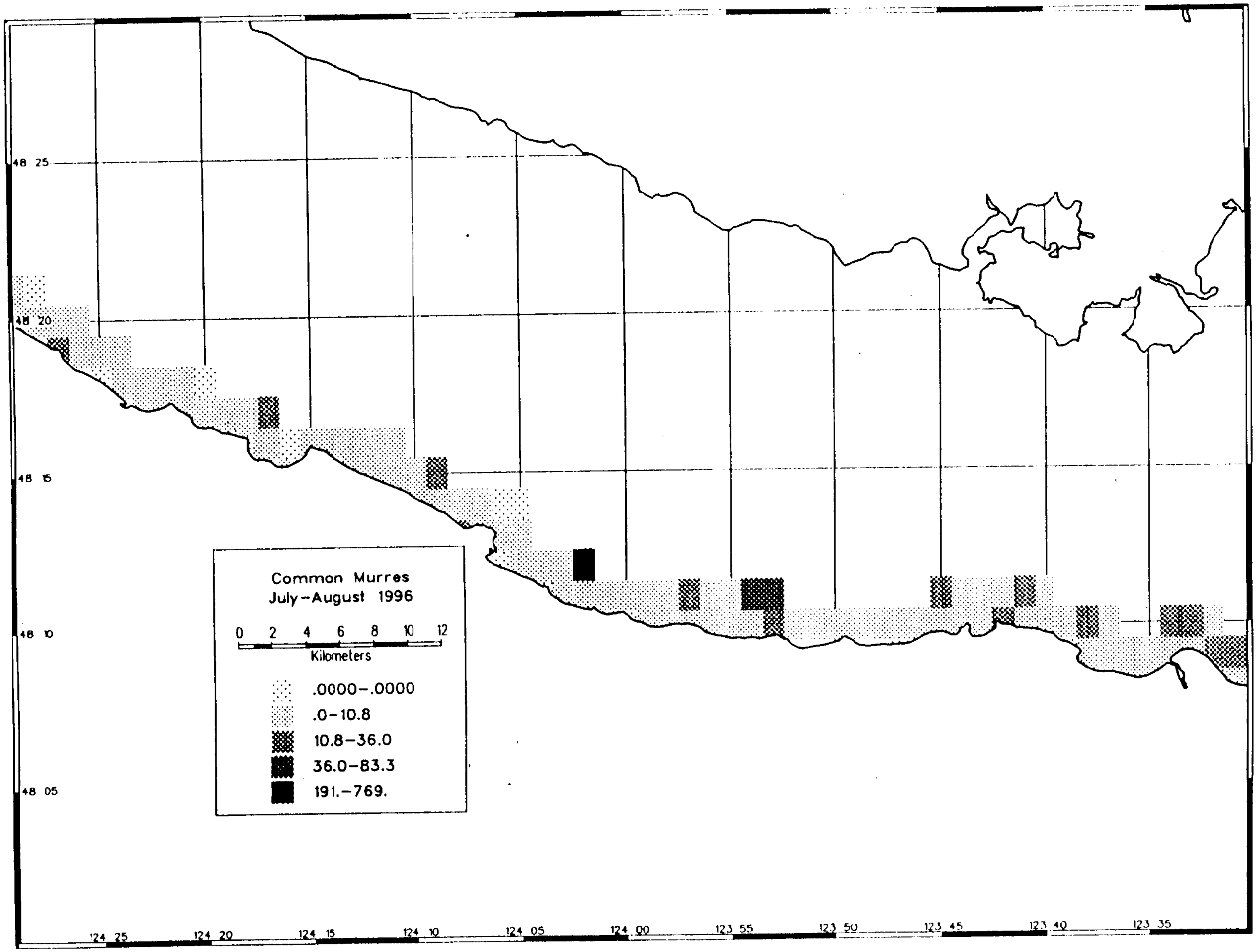

Common Murres
July-August 1996
0 2 4 6 8 10 12
Kilometers
.0000-.0000
.0-10.8
10.8-36.0
36.0-83.3
191.-769.
48 25
48 20
48 15
48 10
48 05
124 25
124 20
124 15
124 10
124 05
124 00
123 55
123 50
123 45
123 40
123 35

Figure 9b

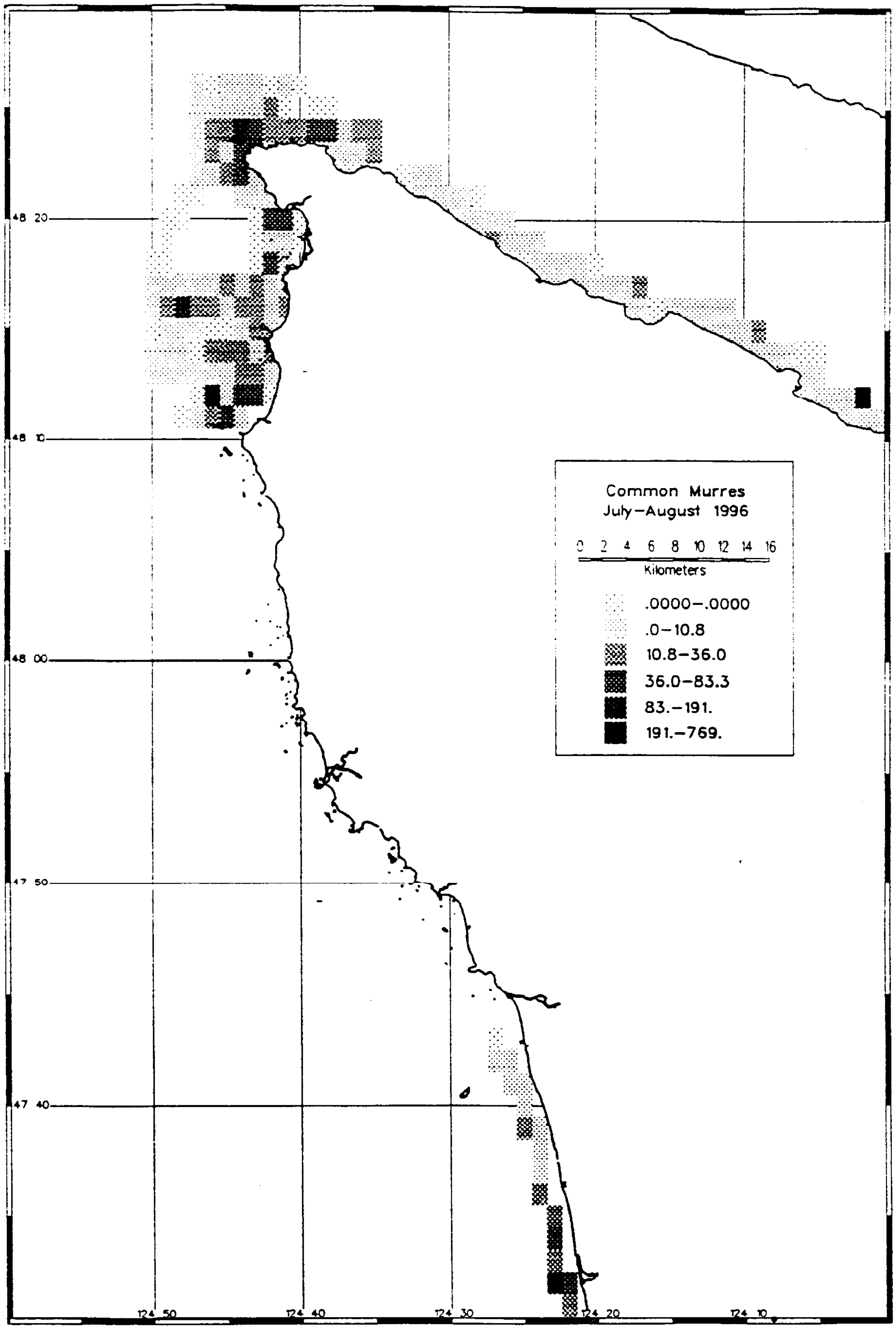

48 20
48 10
48 00
47 50
47 40
124 50
124 40
124 30
124 20
124 10
Common Murres
July–August 1996
0 2 4 6 8 10 12 14 16
Kilometers
.0000–.0000
.0–10.8
10.8–36.0
36.0–83.3
83.–191.
191.–769.

Figure 9c

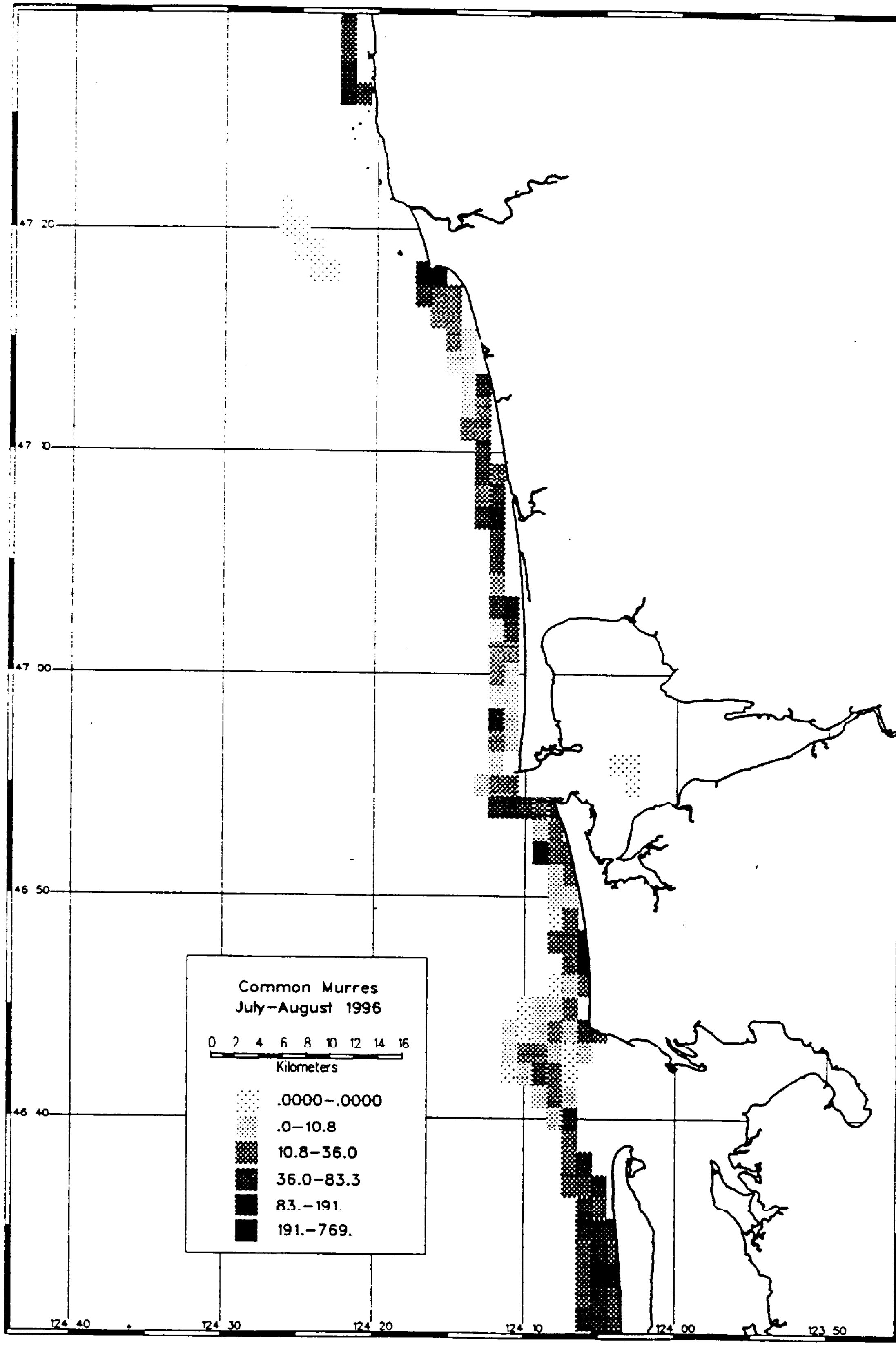
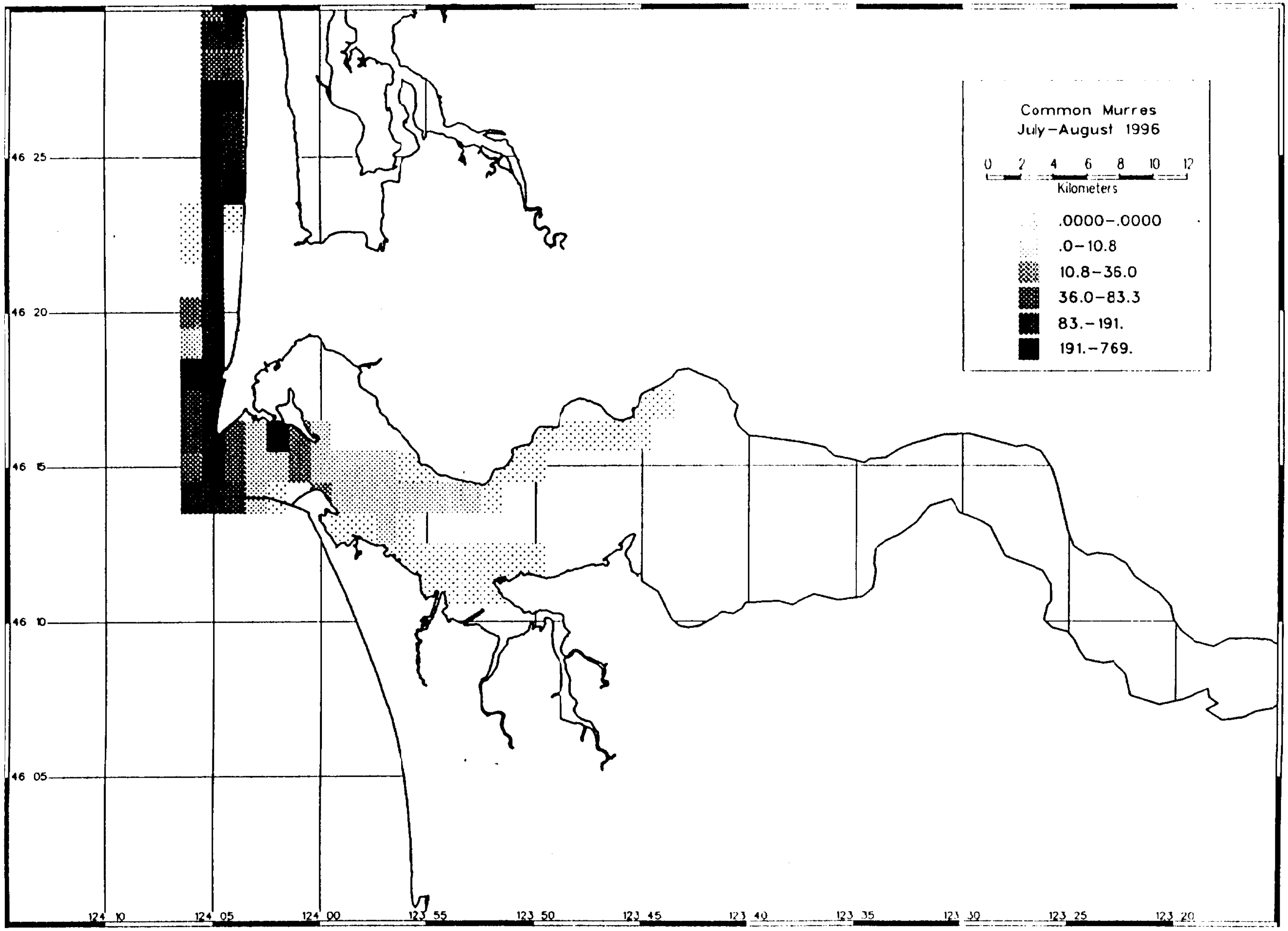

Common Murres
July–August 1996
0 2 4 6 8 10 12 14 16
Kilometers
.0000–.0000
.0–10.8
10.8–36.0
36.0–83.3
83.–191.
191.–769.
47 20
47 10
47 00
46 50
46 40
124 40
124 30
124 20
124 10
124 00
123 50

Figure 9d



Common Murres
July–August 1996
0 2 4 6 8 10 12
Kilometers
.0000–.0000
.0–10.8
10.8–36.0
36.0–83.3
83.–191.
191.–769.
46 25
46 20
46 15
46 10
46 05
124 10
124 05
124 00
123 55
123 50
123 45
123 40
123 35
123 30
123 25
123 20

Figure 10a

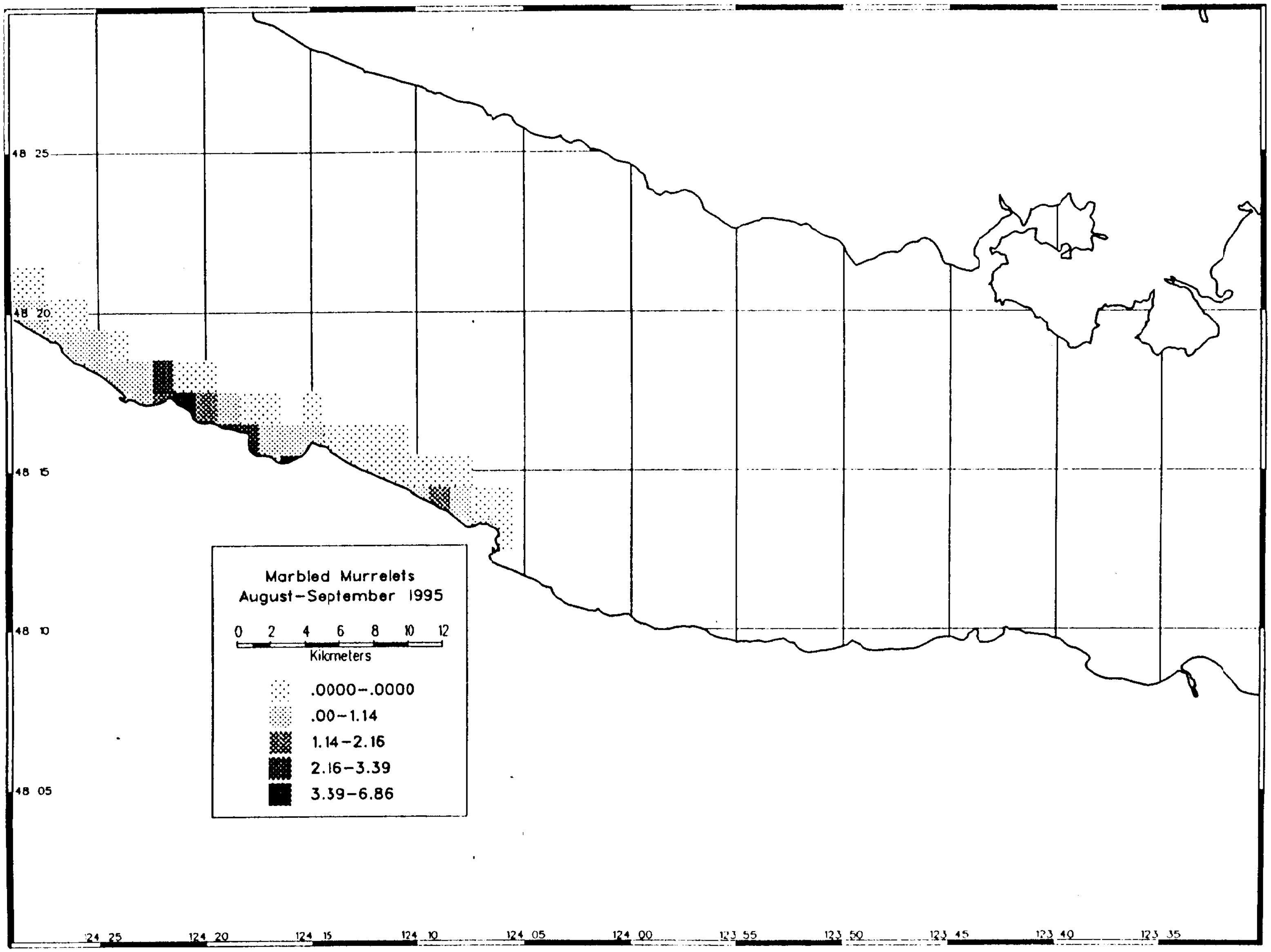

Marbled Murrelets
August-September 1995
0 2 4 6 8 10 12
Kilometers
.0000-.0000
.00-1.14
1.14-2.16
2.16-3.39
3.39-6.86
48 25
48 20
48 15
48 10
48 05
124 25
124 20
124 15
124 10
124 05
124 00
123 55
123 50
123 45
123 40
123 35

Figure 10b

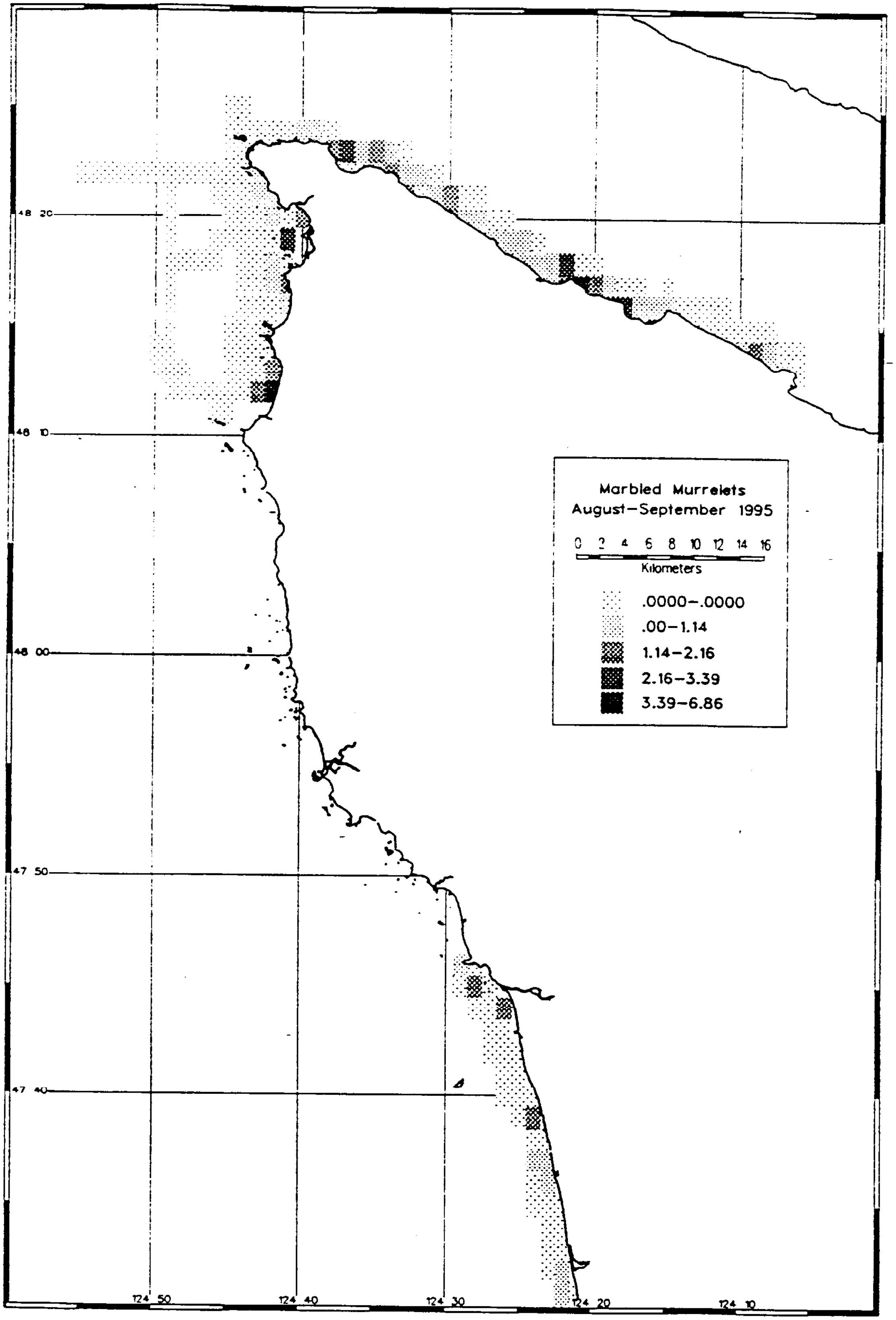
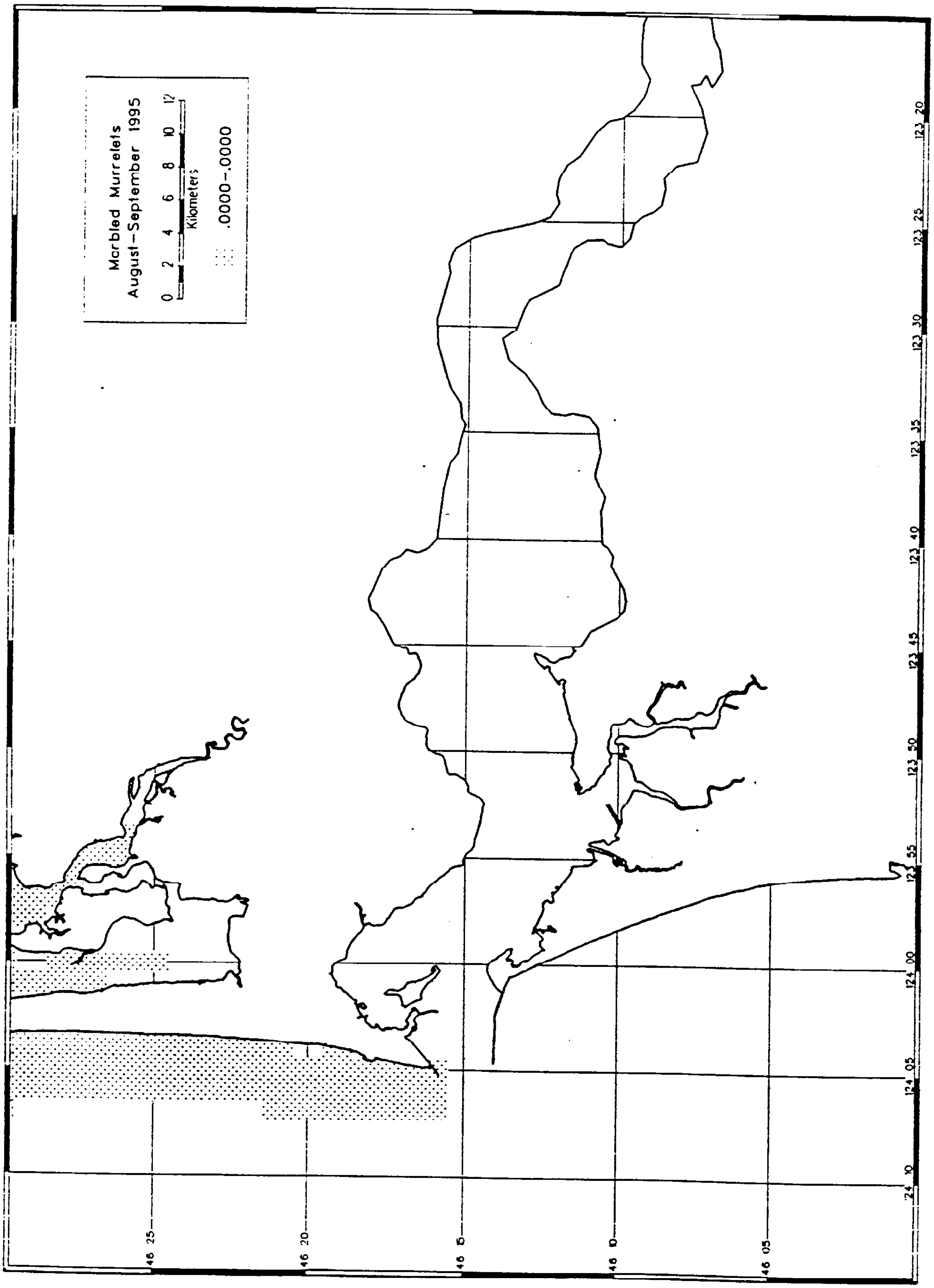
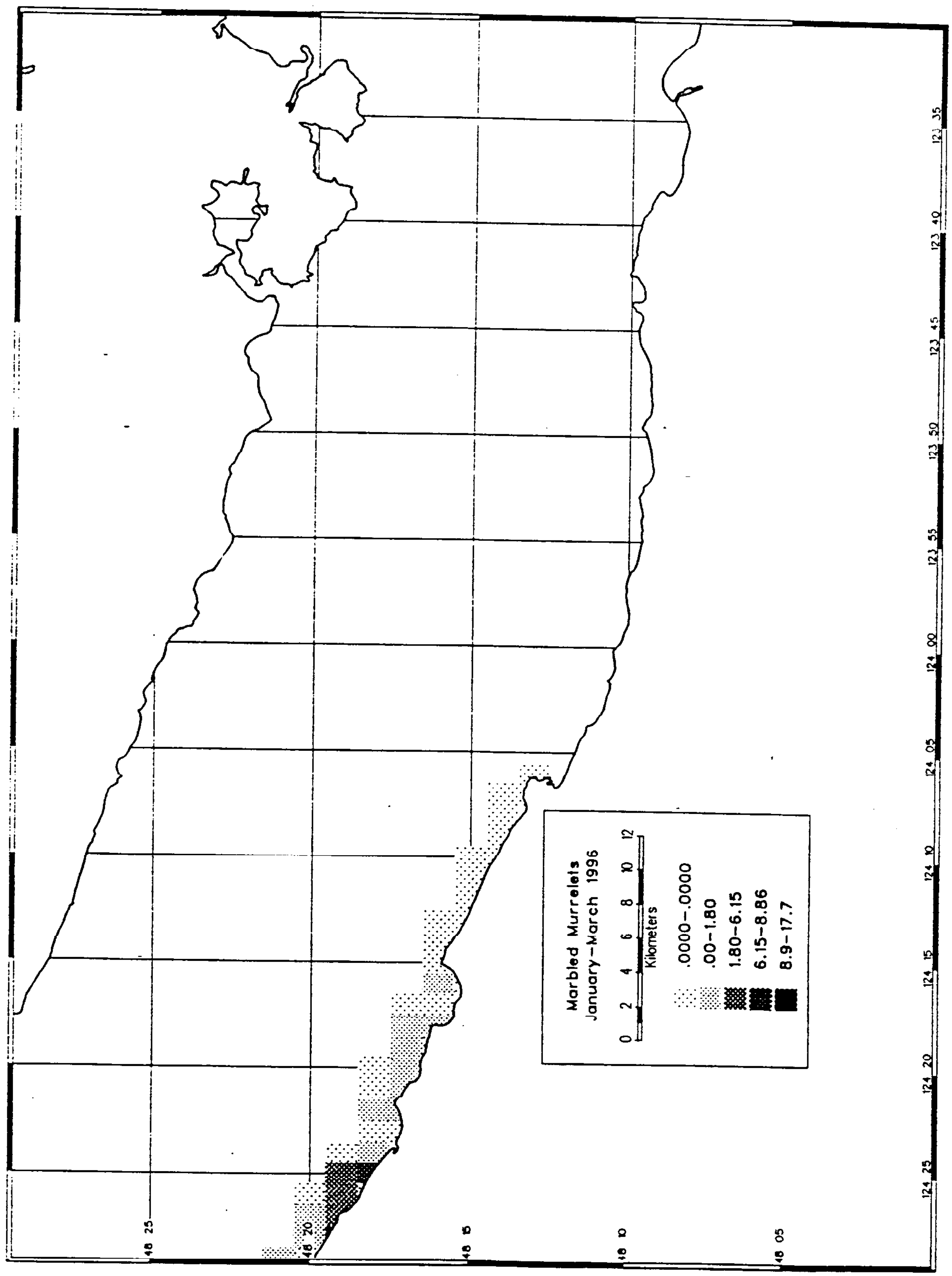

48 20
48 10
48 00
47 50
47 40
124 50
124 40
124 30
124 20
124 10
Marbled Murrelets
August–September 1995
0 2 4 6 8 10 12 14 16
Kilometers
.0000–.0000
.00–1.14
1.14–2.16
2.16–3.39
3.39–6.86

Figure 10d



Marbled Murrelets
August-September 1995
0 2 4 6 8 10 12
Kilometers
.0000-.0000
123 20
123 25
123 30
123 35
123 40
123 45
123 50
123 55
124 00
124 05
124 10
46 25
46 20
46 15
46 10
46 05

Figure 11a



Marbled Murrelets
January-March 1996
0 2 4 6 8 10 12
Kilometers
.0000-.0000
.00-1.80
1.80-6.15
6.15-8.86
8.9-17.7

Figure 11b

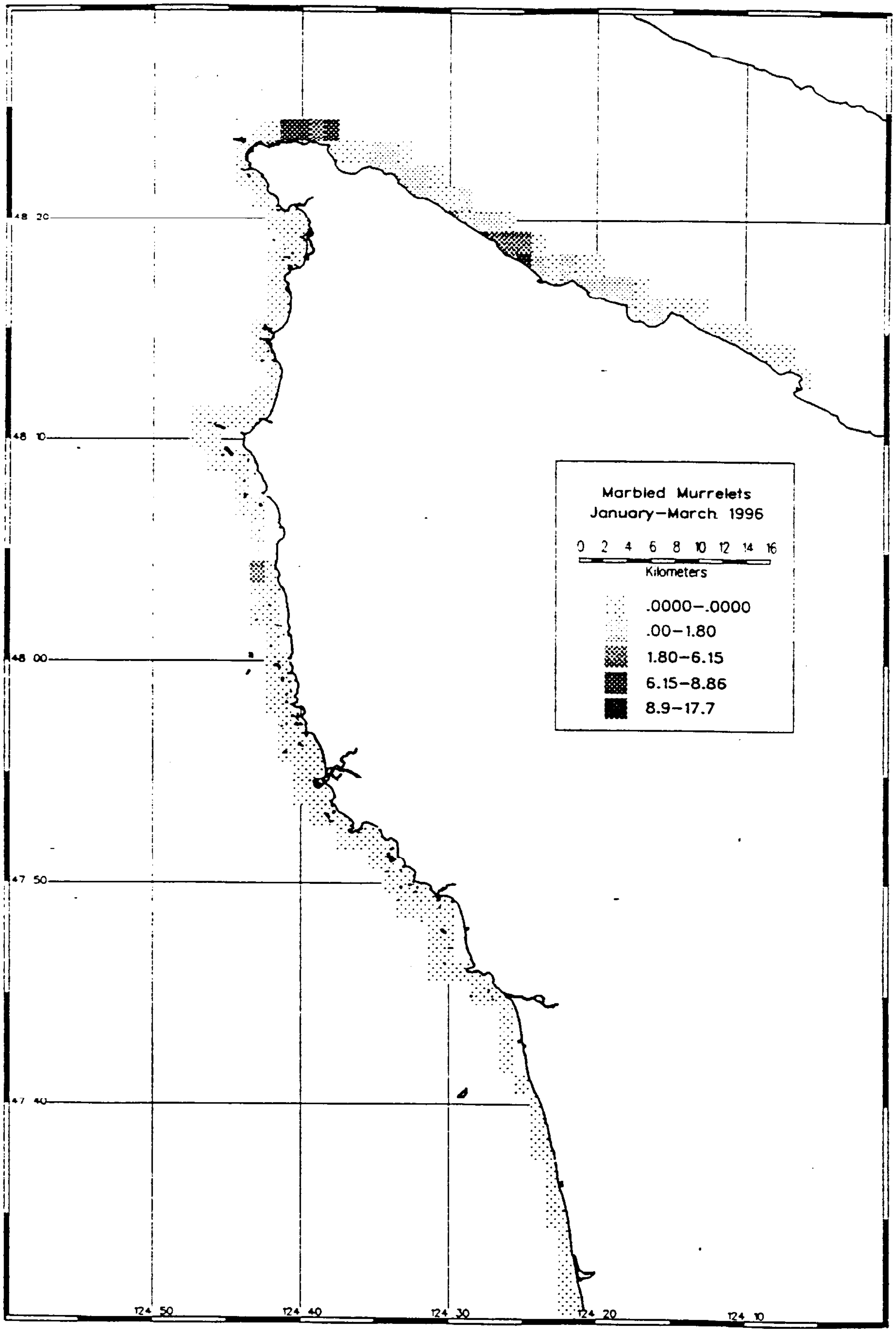

Marbled Murrelets
January–March 1996
0 2 4 6 8 10 12 14 16
Kilometers
.0000–.0000
.00–1.80
1.80–6.15
6.15–8.86
8.9–17.7
48 20
48 10
48 00
47 50
47 40
124 50
124 40
124 30
124 20
124 10

Figure 11c

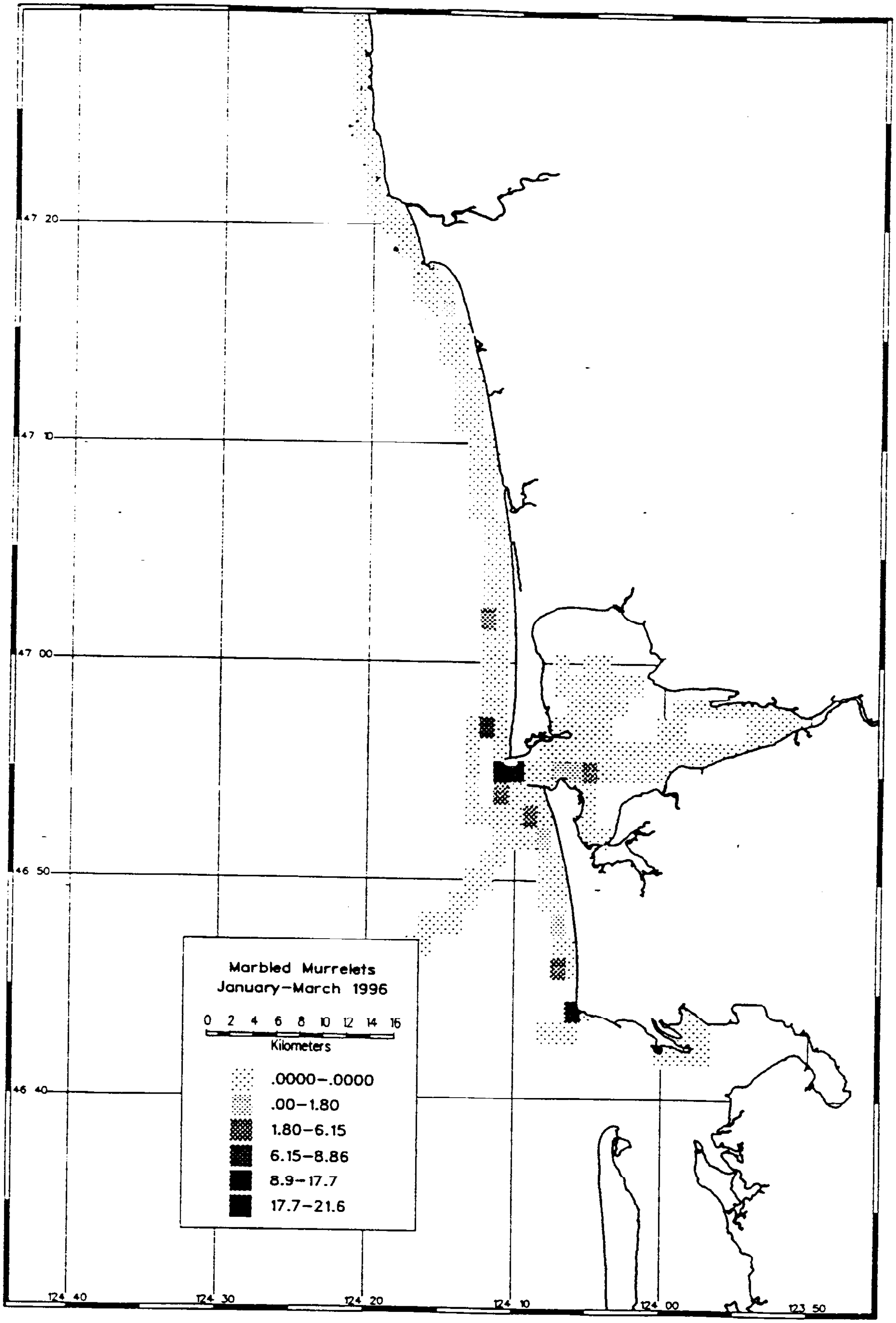

Marbled Murrelets
January–March 1996
0 2 4 6 8 10 12 14 16
Kilometers
.0000–.0000
.00–1.80
1.80–6.15
6.15–8.86
8.9–17.7
17.7–21.6
47 20
47 10
47 00
46 50
46 40
124 40
124 30
124 20
124 10
124 00
123 50

Figure 12a

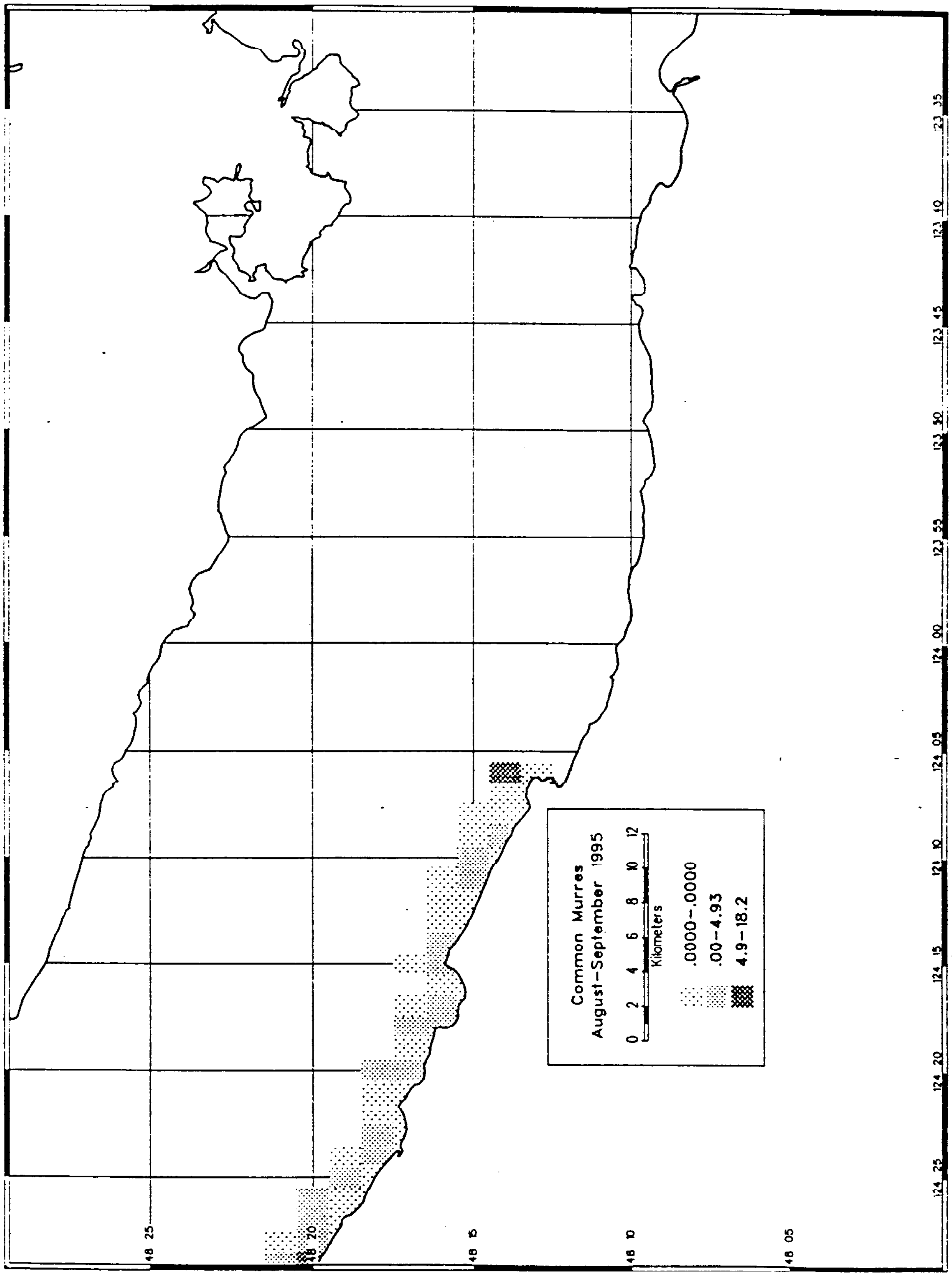

Common Murres
August-September 1995
0 2 4 6 8 10 12
Kilometers
.0000-.0000
.00-4.93
4.9-18.2
48 25
48 20
48 15
48 10
48 05
124 25
124 20
124 15
124 10
124 05
124 00
123 55
123 50
123 45
123 40
123 35

Figure 12b

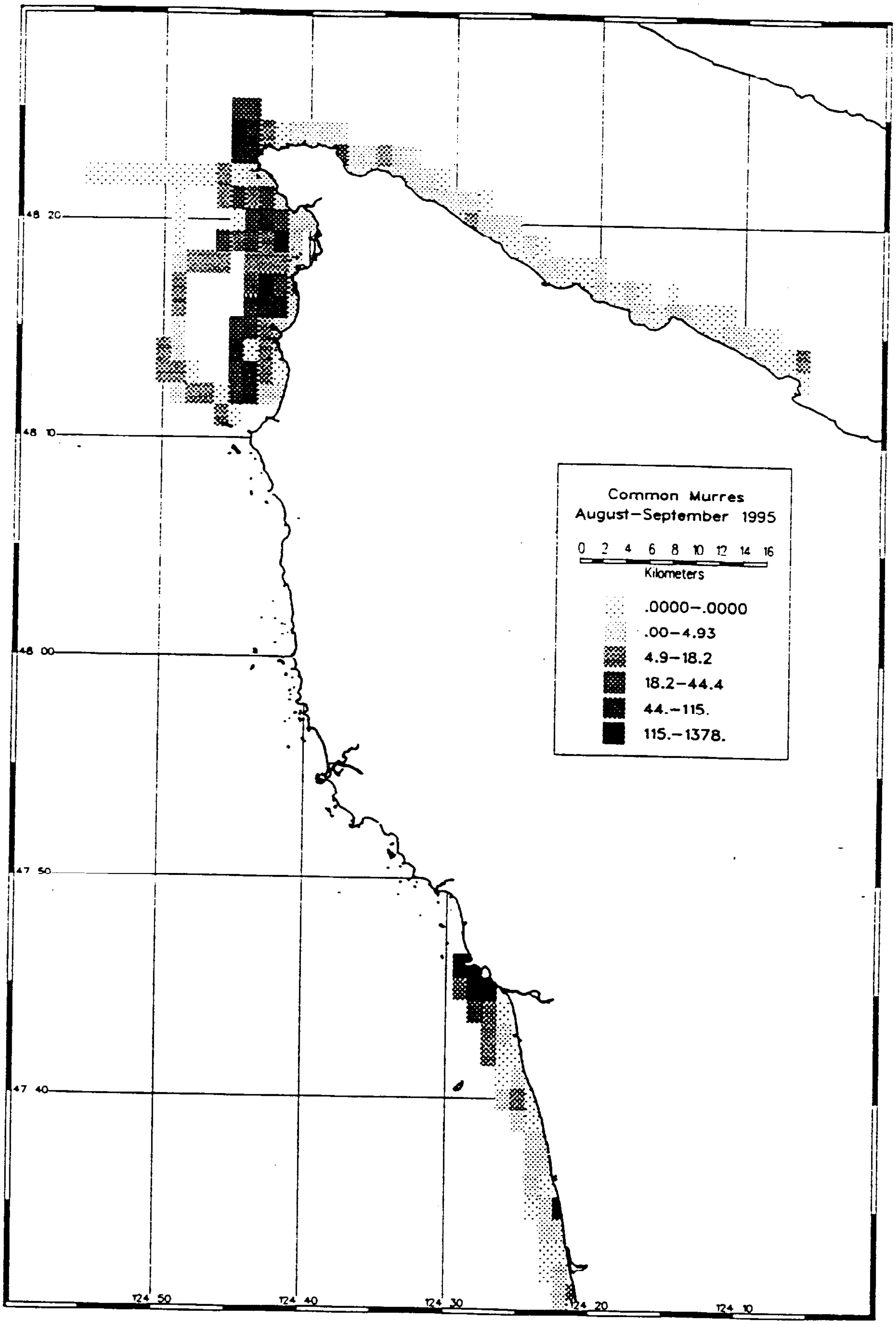
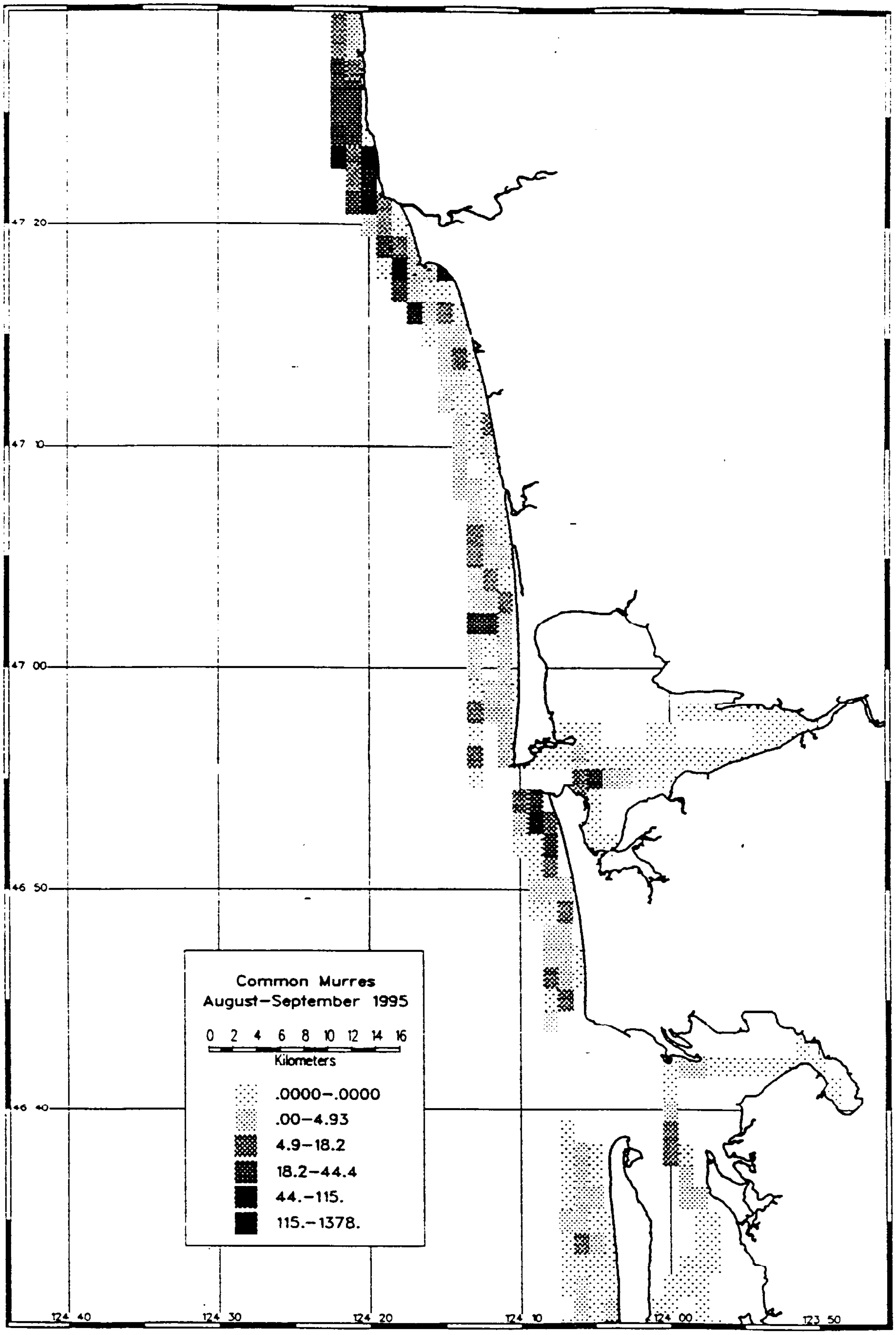

48 20
48 10
48 00
47 50
47 40
124 50
124 40
124 30
124 20
124 10
Common Murres
August-September 1995
0 2 4 6 8 10 12 14 16
Kilometers
.0000-.0000
.00-4.93
4.9-18.2
18.2-44.4
44.-115.
115.-1378.

Figure 12c



47 20
47 10
47 00
46 50
46 40
124 40
124 30
124 20
124 10
124 00
123 50
Common Murres
August–September 1995
0 2 4 6 8 10 12 14 16
Kilometers
.0000–.0000
.00–4.93
4.9–18.2
18.2–44.4
44.–115.
115.–1378.

Figure 12d

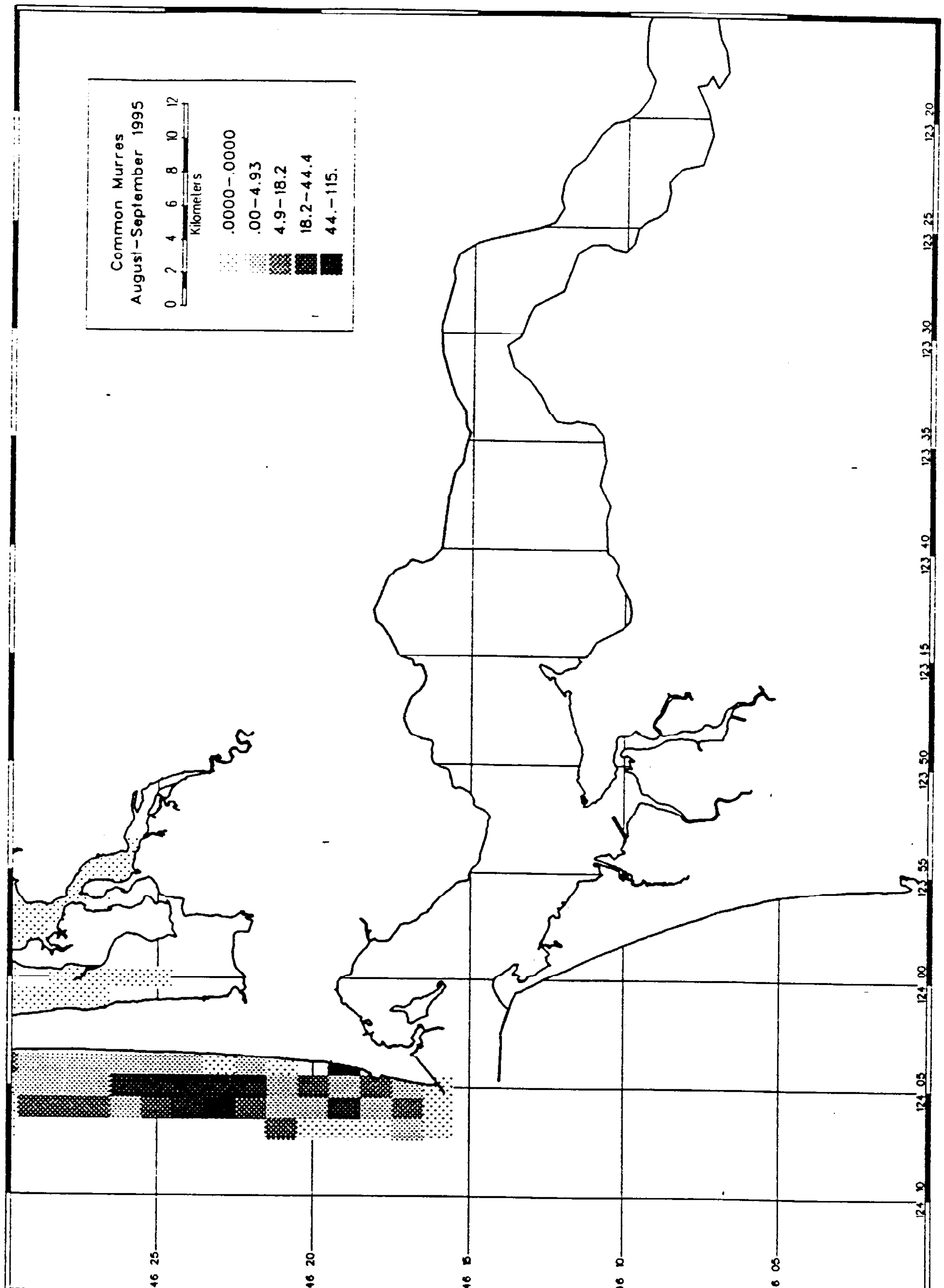
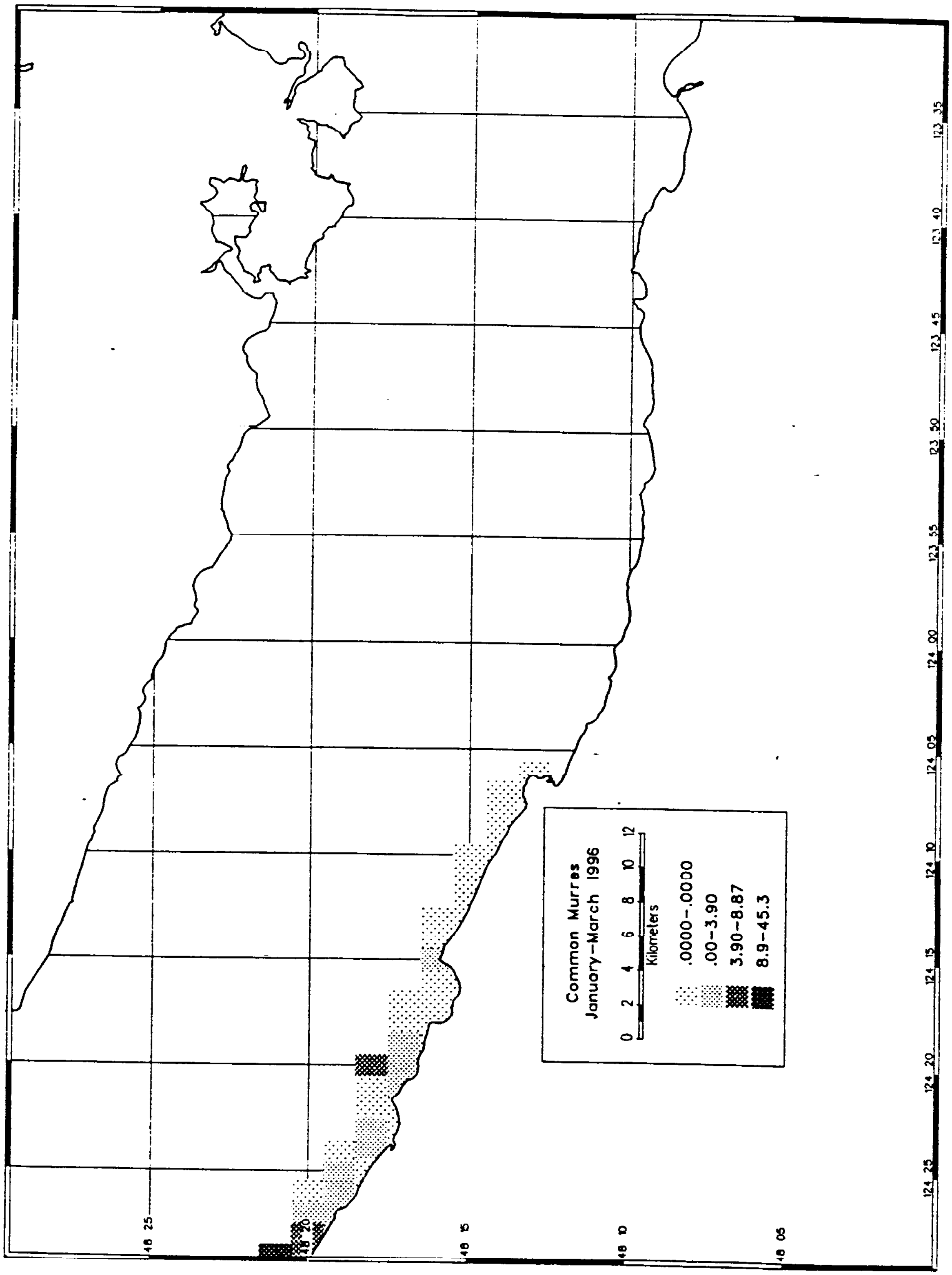

Common Murres
August-September 1995
0 2 4 6 8 10 12
Kilometers
.0000-.0000
.00-4.93
4.9-18.2
18.2-44.4
44.-115.
123 20
123 25
123 30
123 35
123 40
123 45
123 50
123 55
124 00
124 05
124 10
46 25
46 20
46 15
46 10
46 05

Figure 13a



Common Murres
January-March 1996
0 2 4 6 8 10 12
Kilometers
.0000-.0000
.00-3.90
3.90-8.87
8.9-45.3

Figure 13b

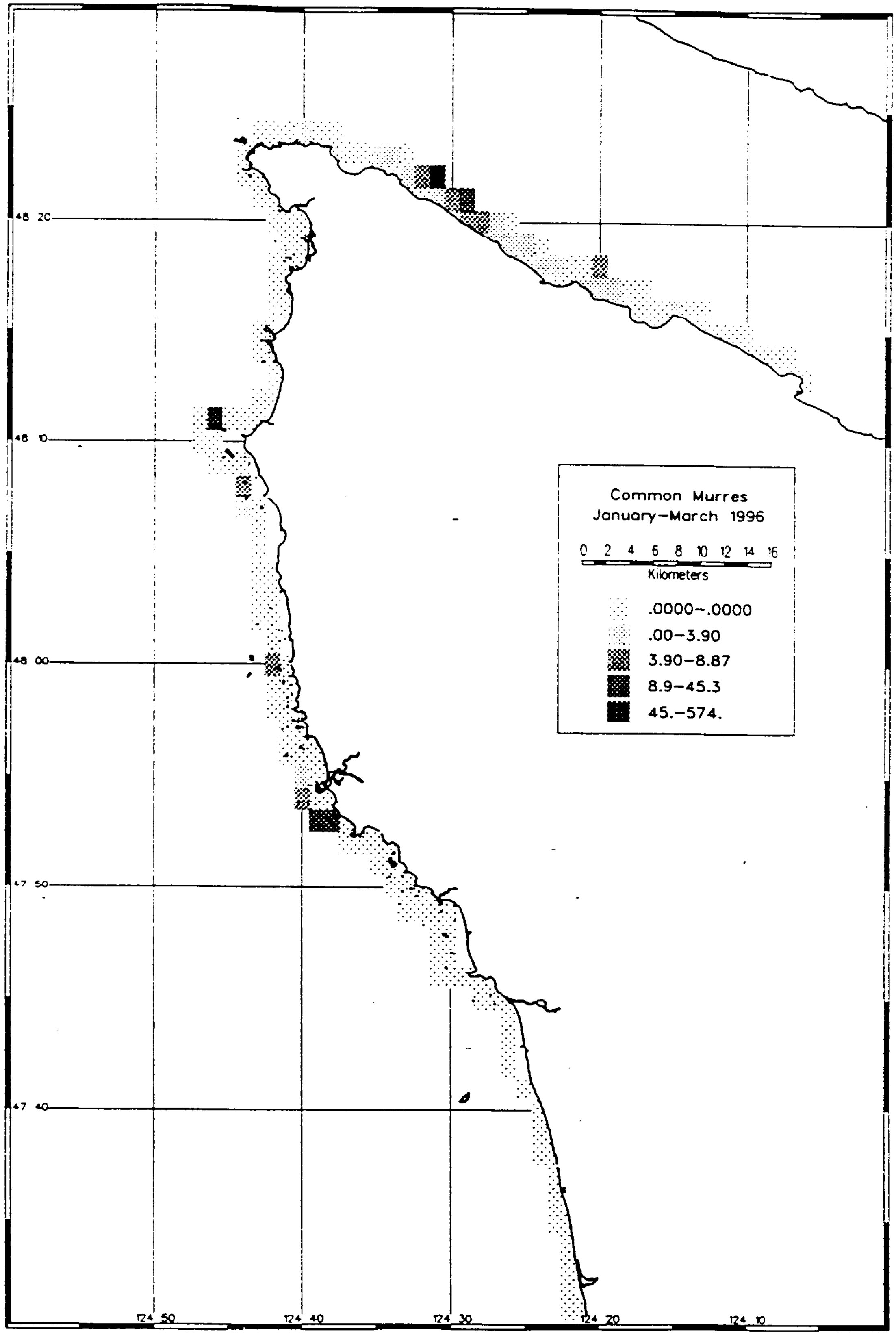

Common Murres
January–March 1996
0 2 4 6 8 10 12 14 16
Kilometers
.0000–.0000
.00–3.90
3.90–8.87
8.9–45.3
45.–574.
48 20
48 10
48 00
47 50
47 40
124 50
124 40
124 30
124 20
124 10

Figure 13c

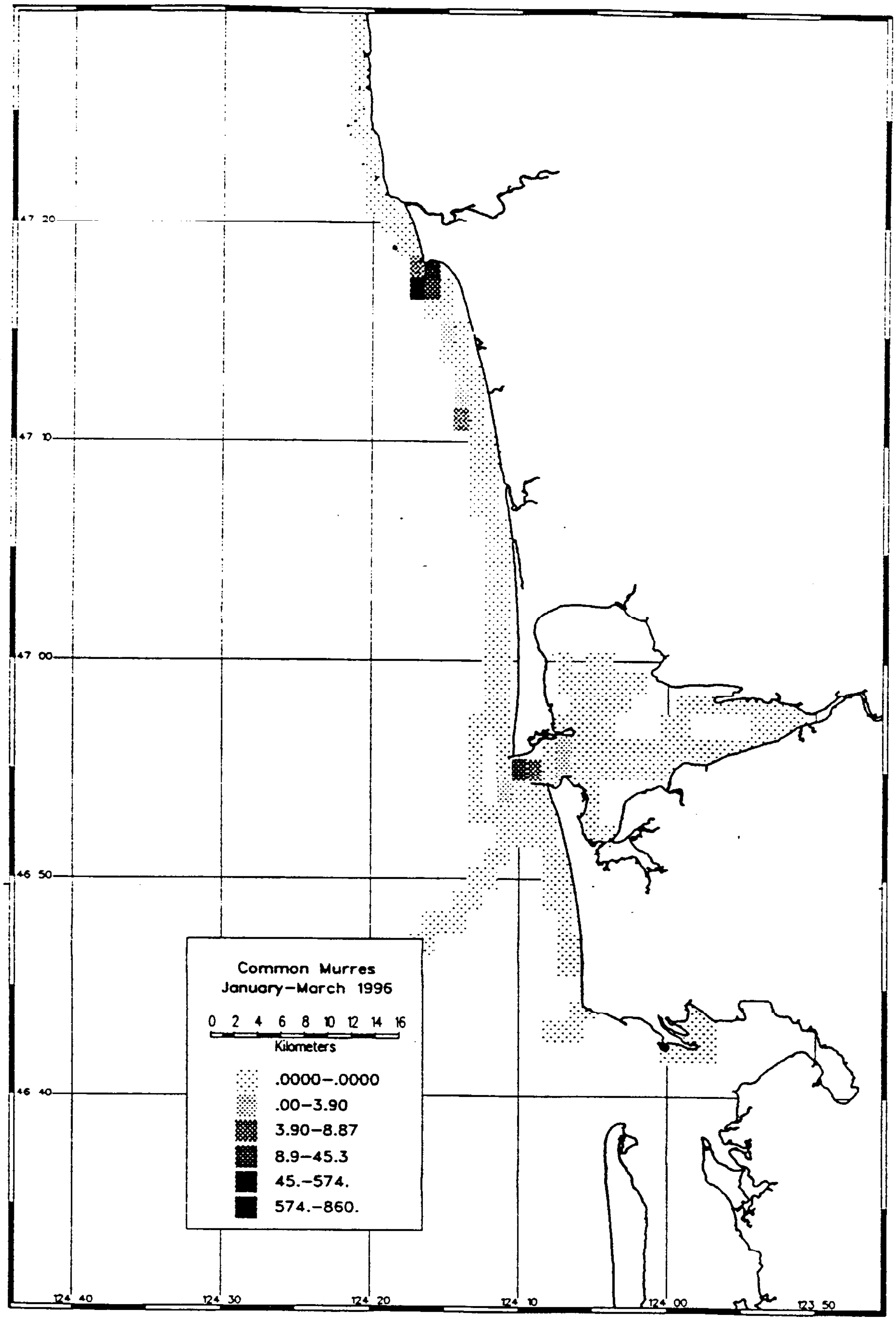
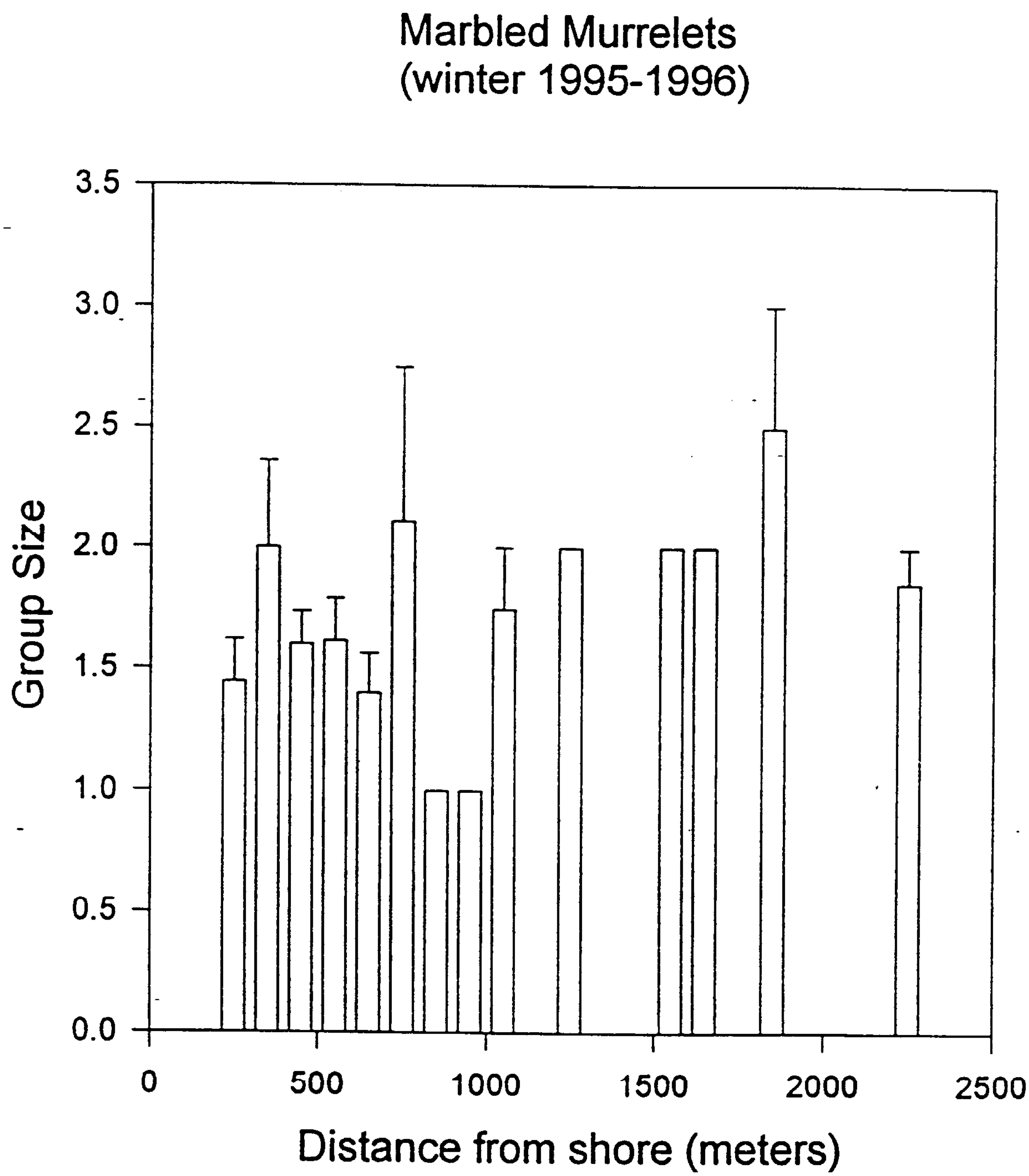

Common Murres
January–March 1996
0 2 4 6 8 10 12 14 16
Kilometers
.0000–.0000
.00–3.90
3.90–8.87
8.9–45.3
45.–574.
574.–860.
47 20
47 10
47 00
46 50
46 40
124 40
124 30
124 20
124 10
124 00
123 50

Figure 14



Marbled Murrelets
(winter 1995-1996)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Group Size
0
500
1000
1500
2000
2500
Distance from shore (meters)

Figure 15

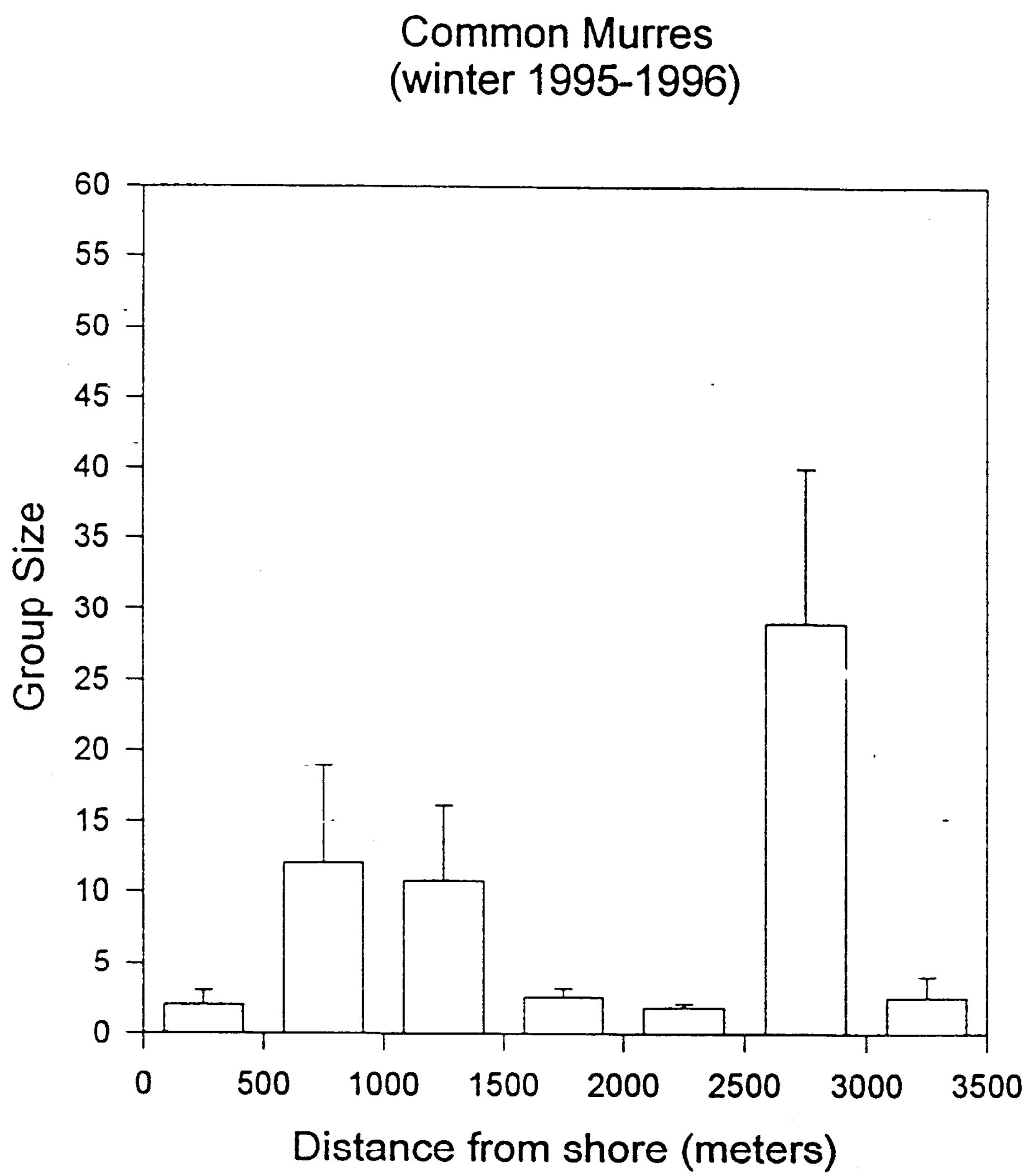

Common Murres
(winter 1995-1996)
60
55
50
45
40
35
30
25
20
15
10
5
0
Group Size
0
500
1000
1500
2000
2500
3000
3500
Distance from shore (meters)

Figure 16

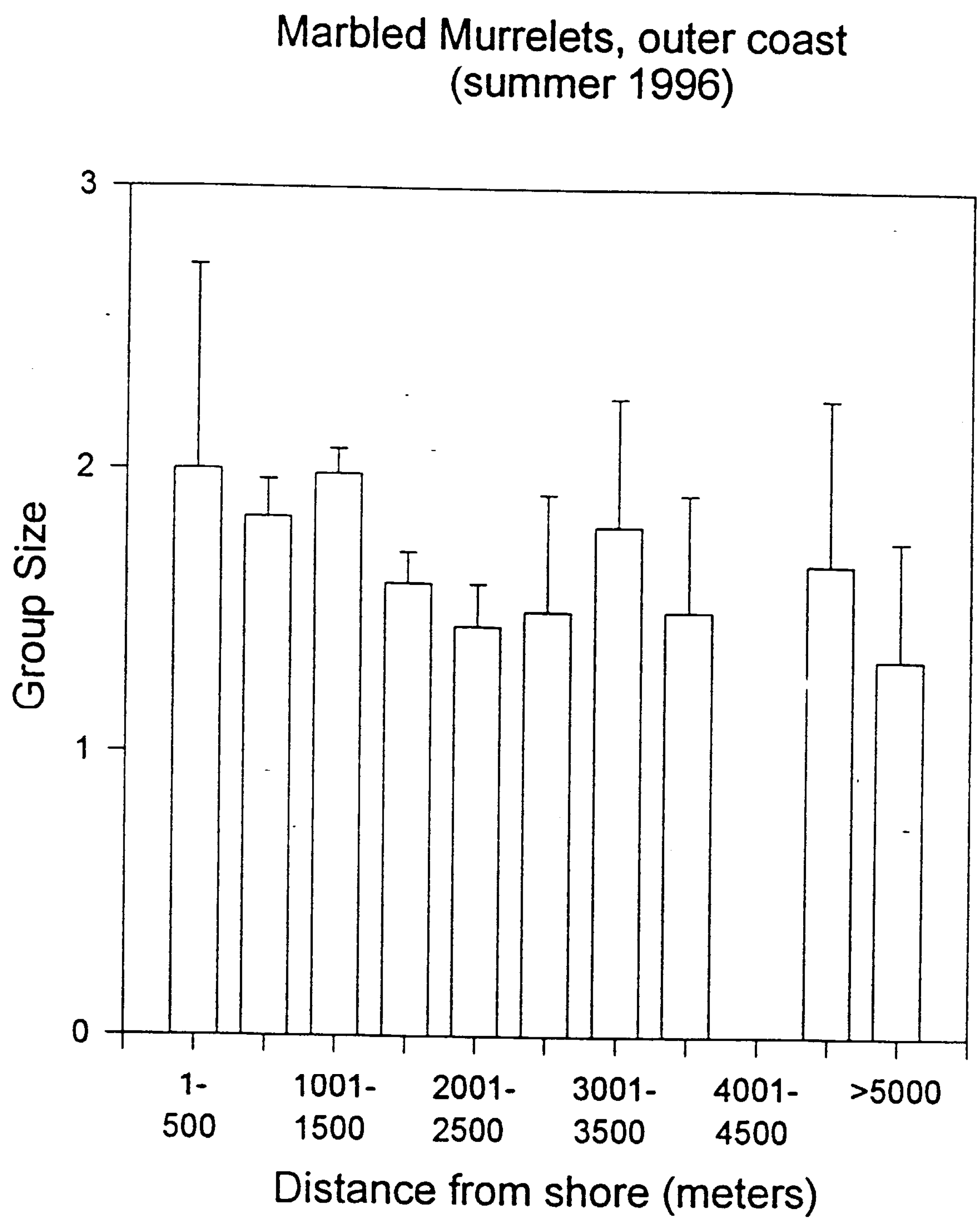

Marbled Murrelets, outer coast
(summer 1996)
3
2
1
0
Group Size
1-
500
1001-
1500
2001-
2500
3001-
3500
4001-
4500
>5000
Distance from shore (meters)

Figure 17

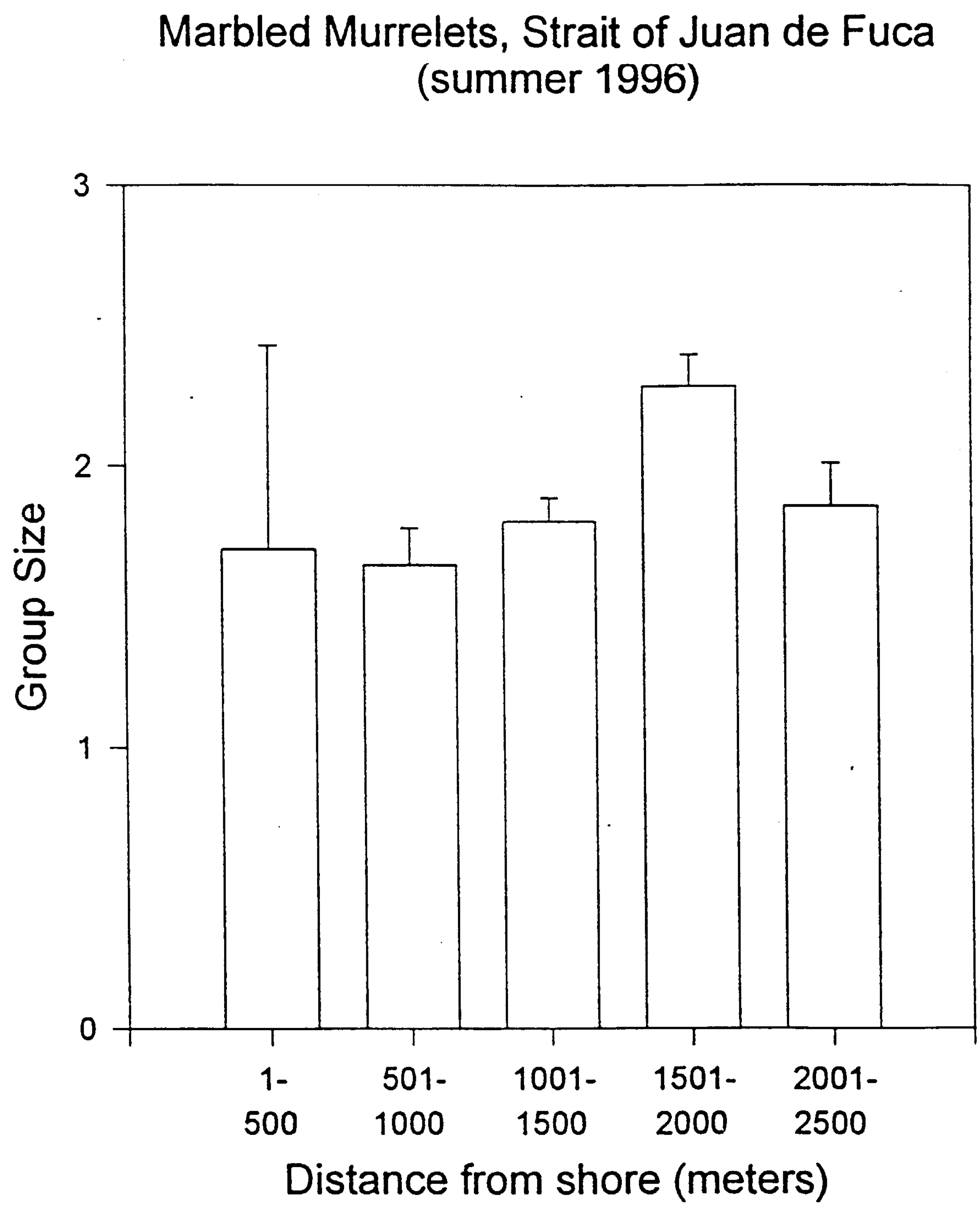
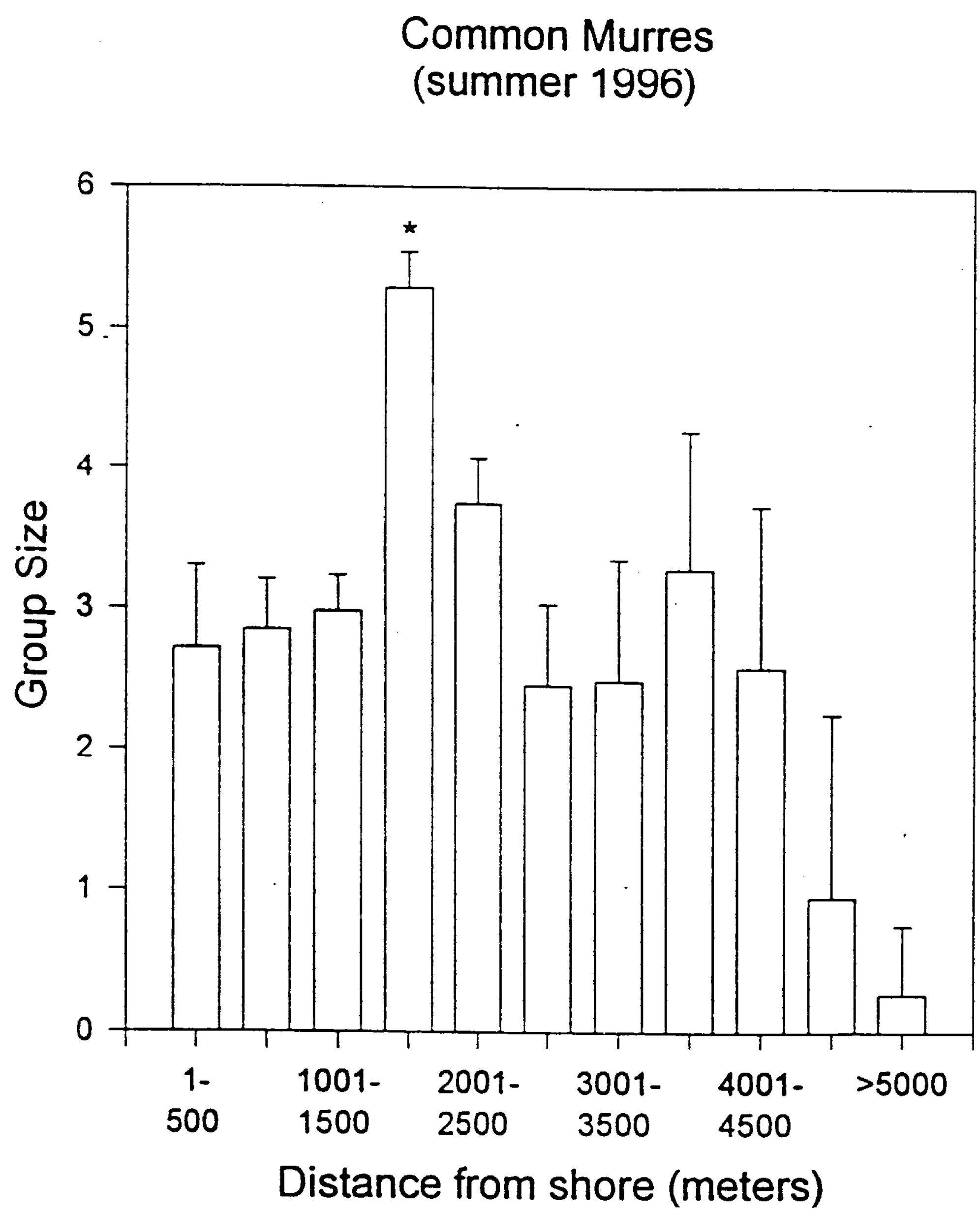
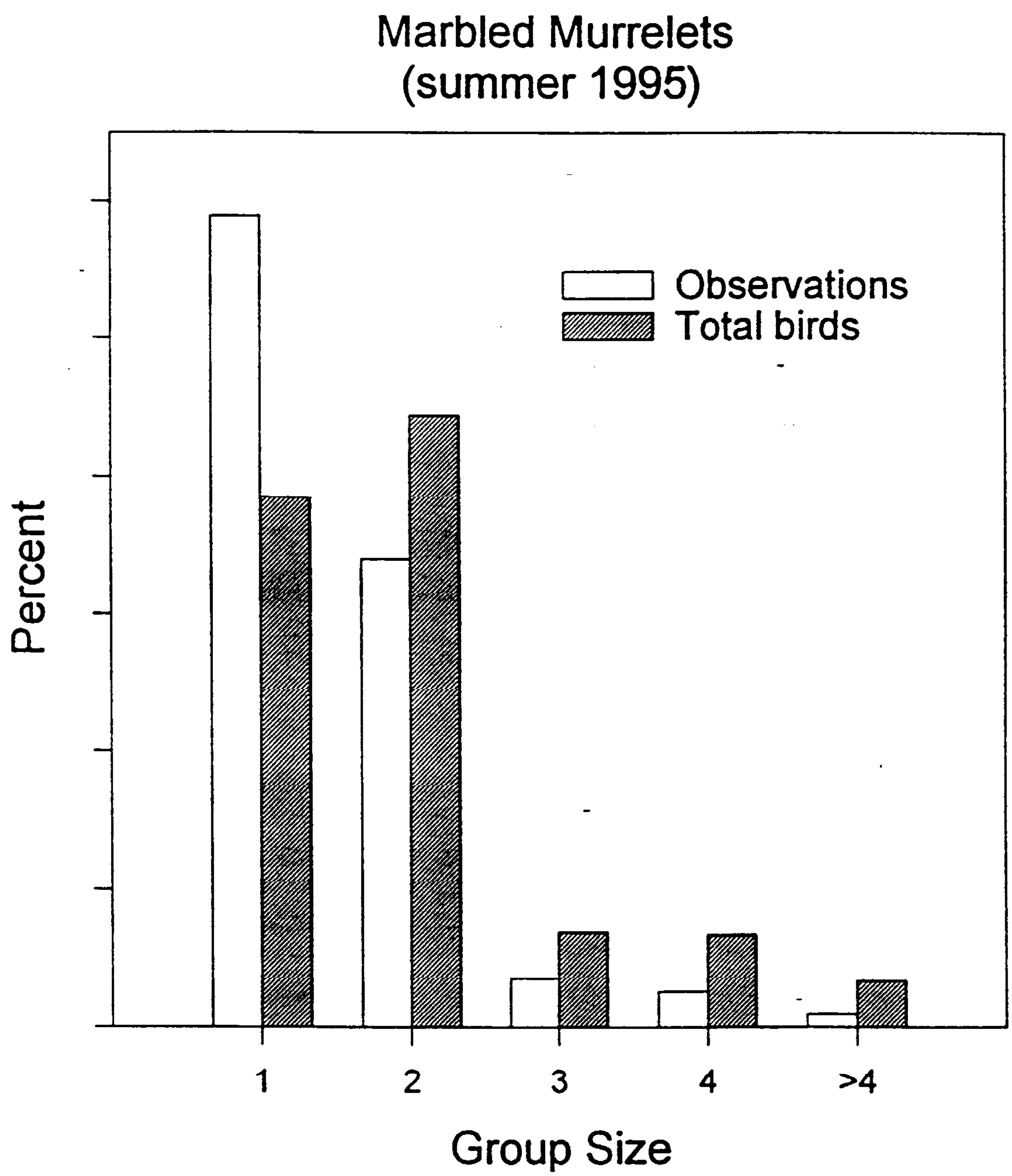

Marbled Murrelets, Strait of Juan de Fuca
(summer 1996)
3
2
1
0
Group Size
1-
500
501-
1000
1001-
1500
1501-
2000
2001-
2500
Distance from shore (meters)

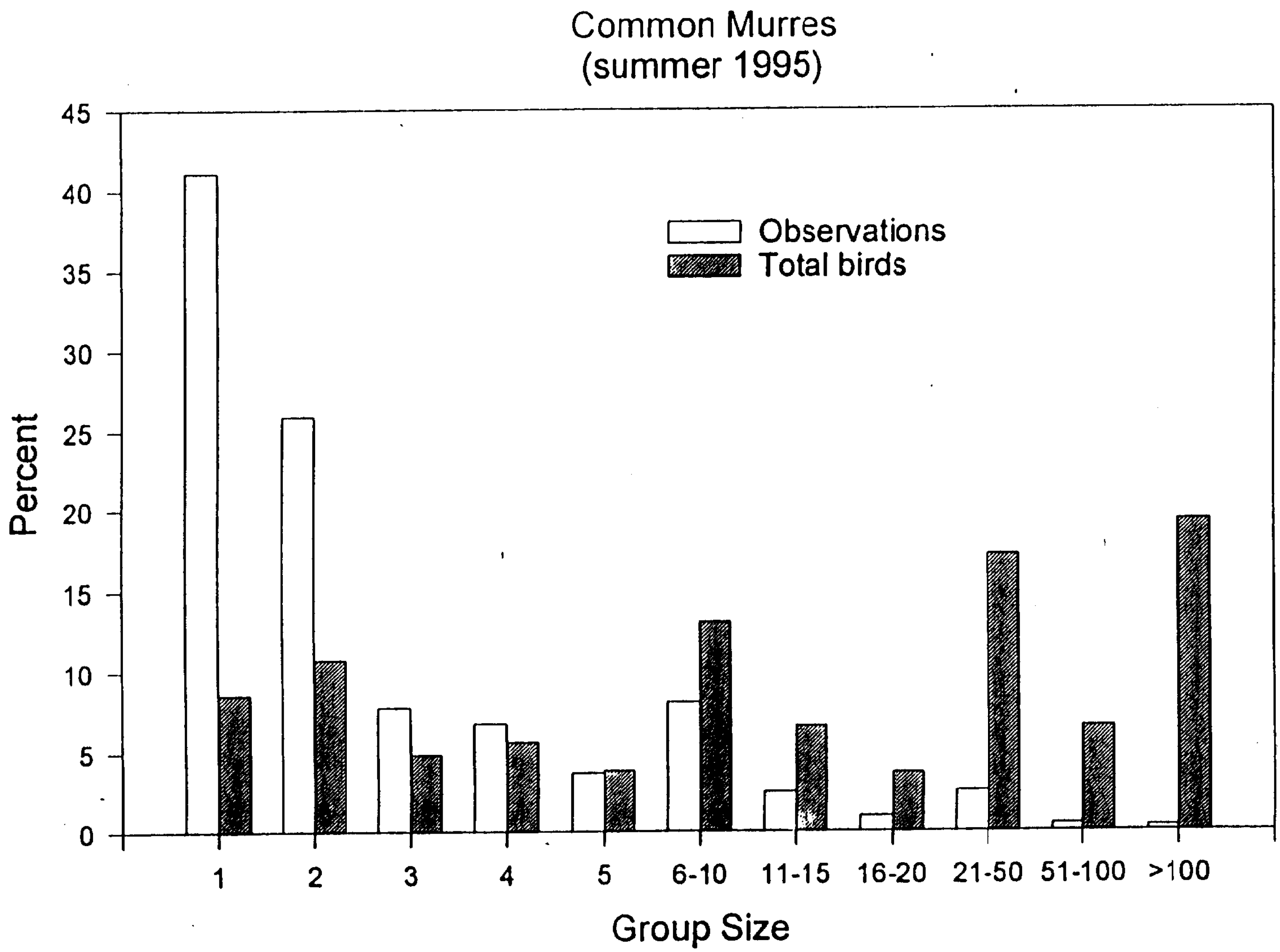
Figure 18



* 5 outliers (of 3926 observations) caused this apparent increase in group size

Figure 19

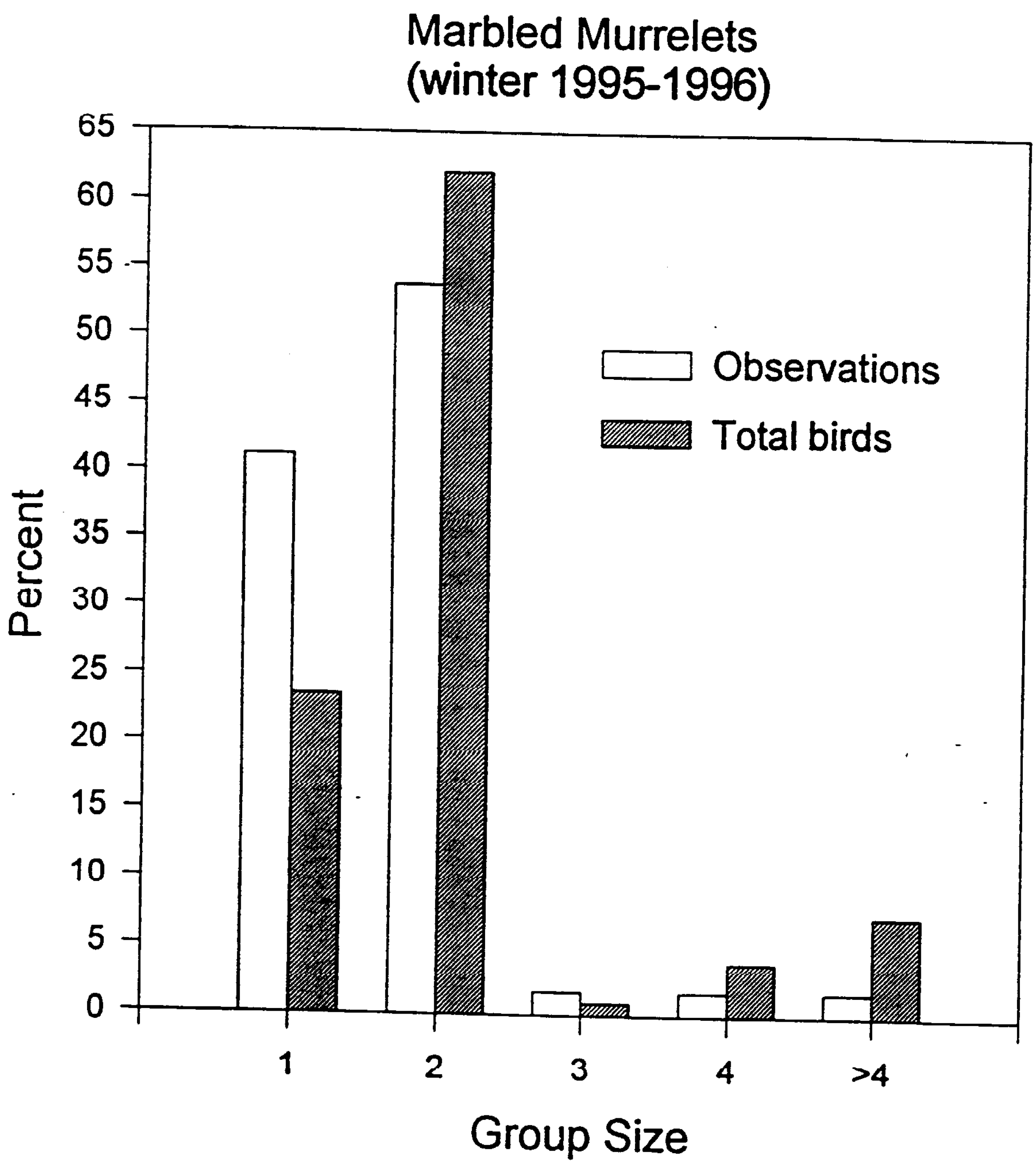

Marbled Murrelets
(summer 1995)
Observations
Total birds
Percent
1
2
3
4
>4
Group Size



Common Murres
(summer 1995)
Observations
Total birds
Percent
45
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6-10
11-15
16-20
21-50
51-100
>100
Group Size

Figure 20

Figure 21



Marbled Murrelets
(winter 1995-1996)
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Percent
Observations
Total birds
1
2
3
4
>4
Group Size

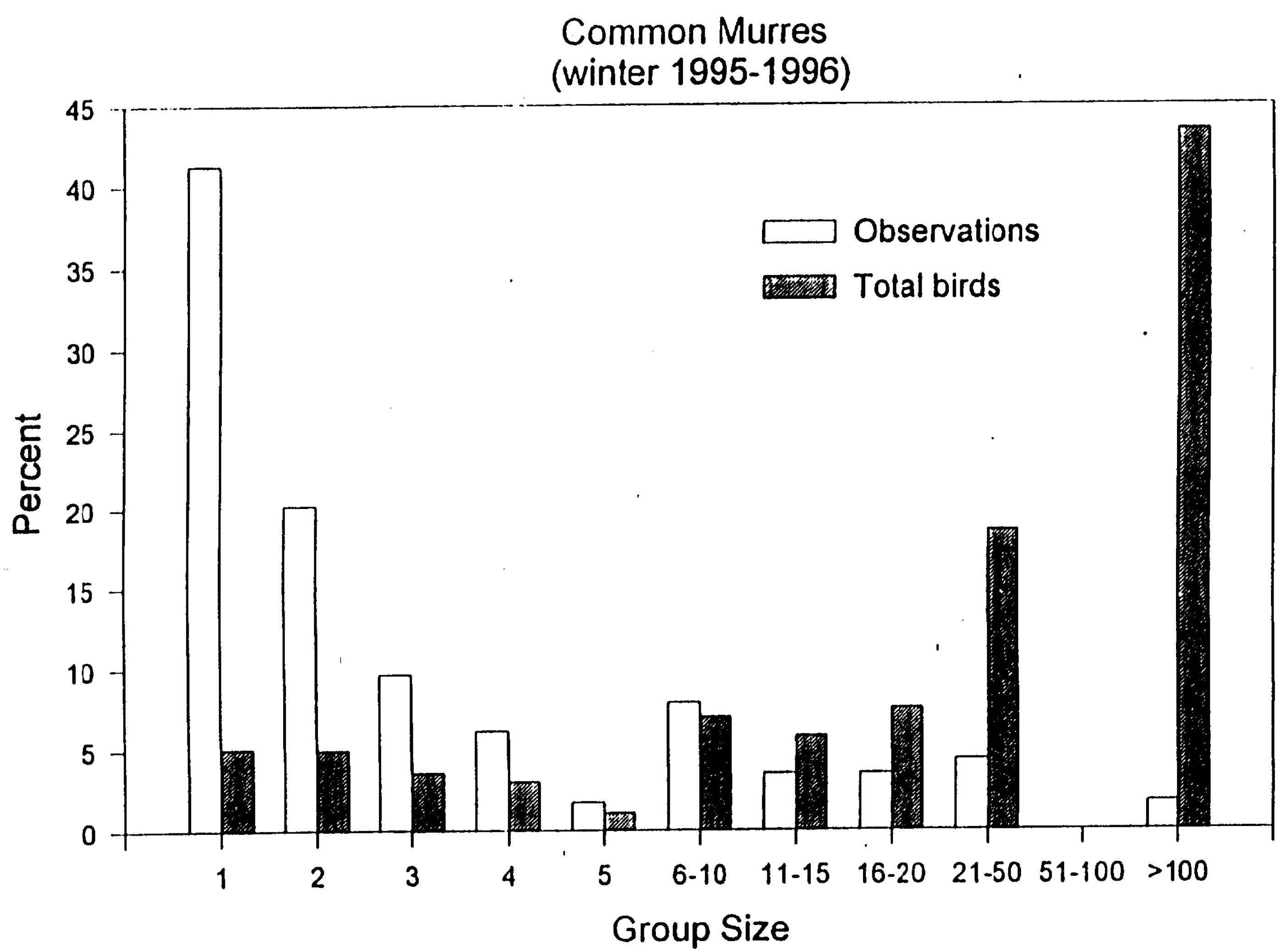

Common Murres
(winter 1995-1996)
Observations
Total birds
Percent
45
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6-10
11-15
16-20
21-50
51-100
>100
Group Size

Figure 22

Figure 23

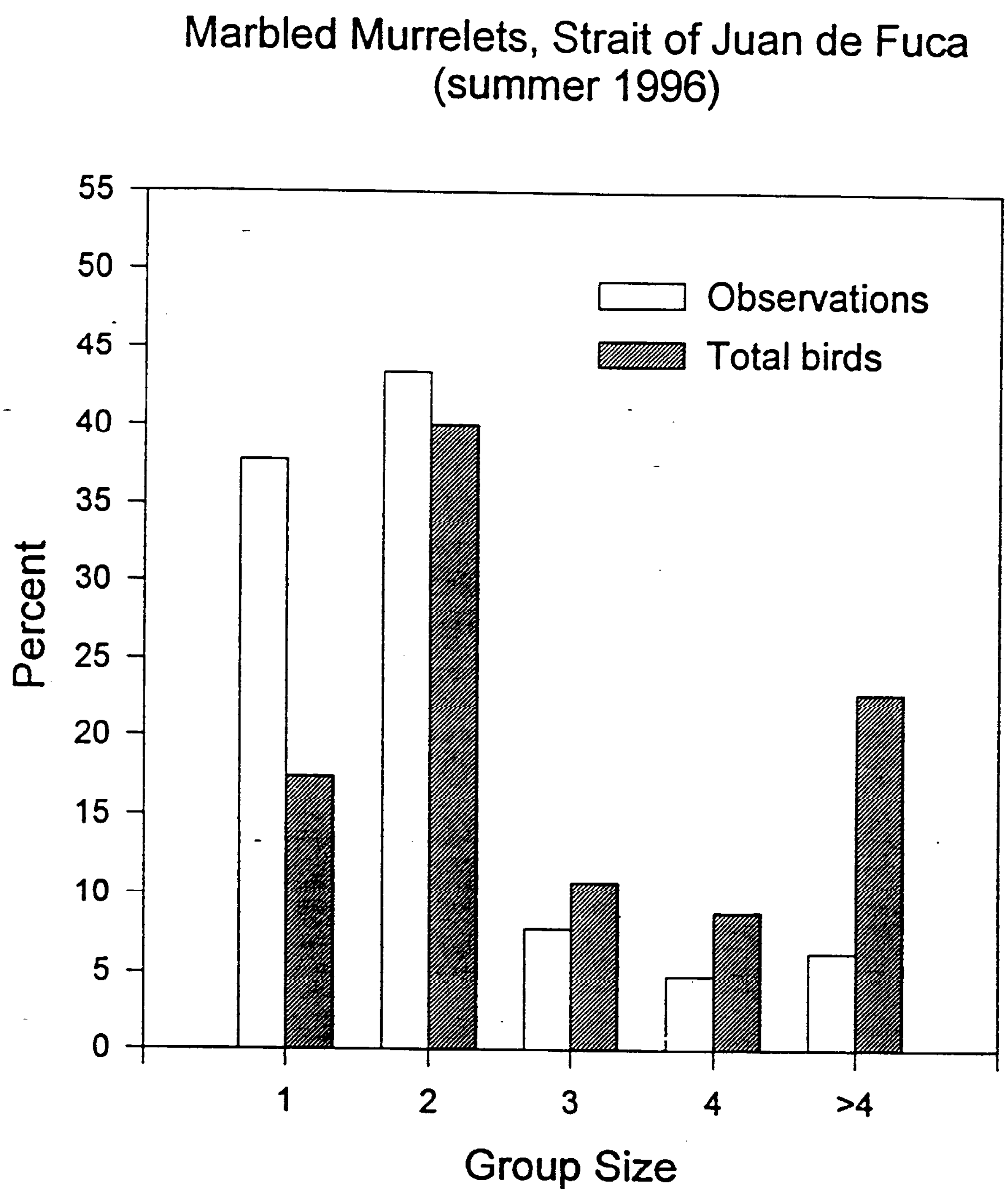

Marbled Murrelets, Strait of Juan de Fuca
(summer 1996)
Observations
Total birds
Percent
55
50
45
40
35
30
25
20
15
10
5
0
1
2
3
4
>4
Group Size

Figure 24

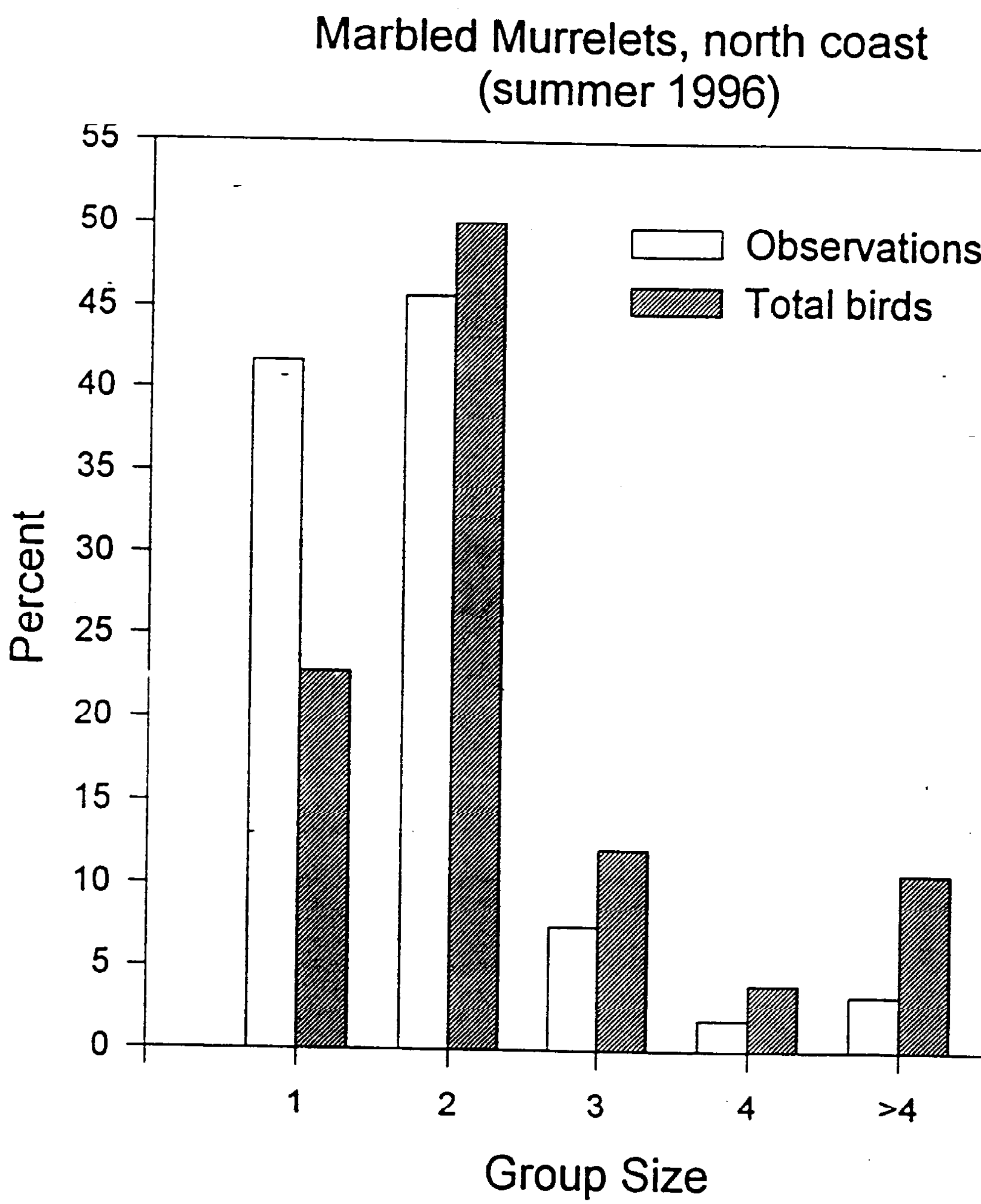
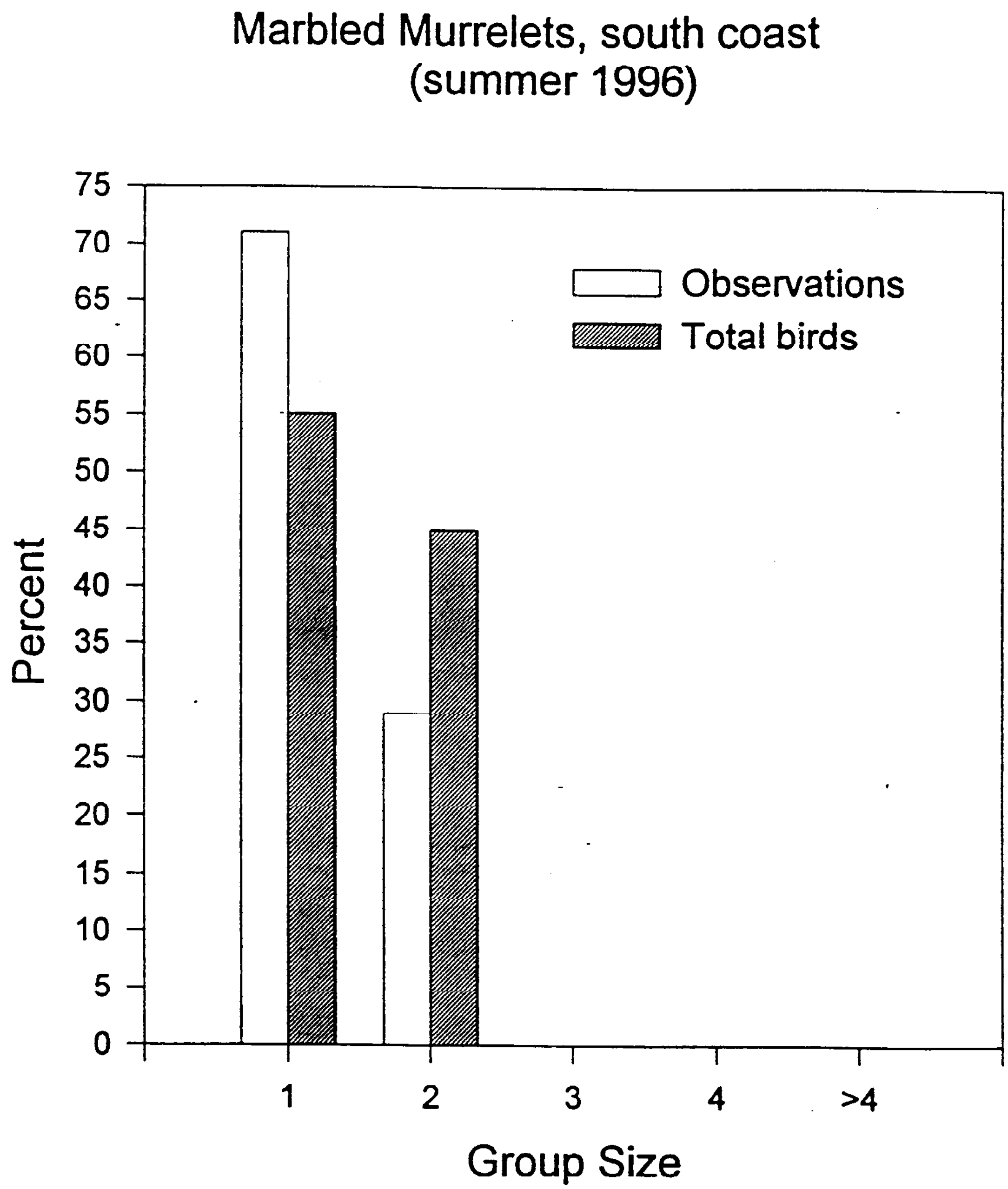

Marbled Murrelets, north coast
(summer 1996)
Observations
Total birds
Percent
55
50
45
40
35
30
25
20
15
10
5
0
1
2
3
4
>4
Group Size

Figure 25


Marbled Murrelets, south coast
(summer 1996)
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Percent
Observations
Total birds
1
2
3
4
>4
Group Size

Common Murres, Strait of Juan de Fuca
(summer 1996)

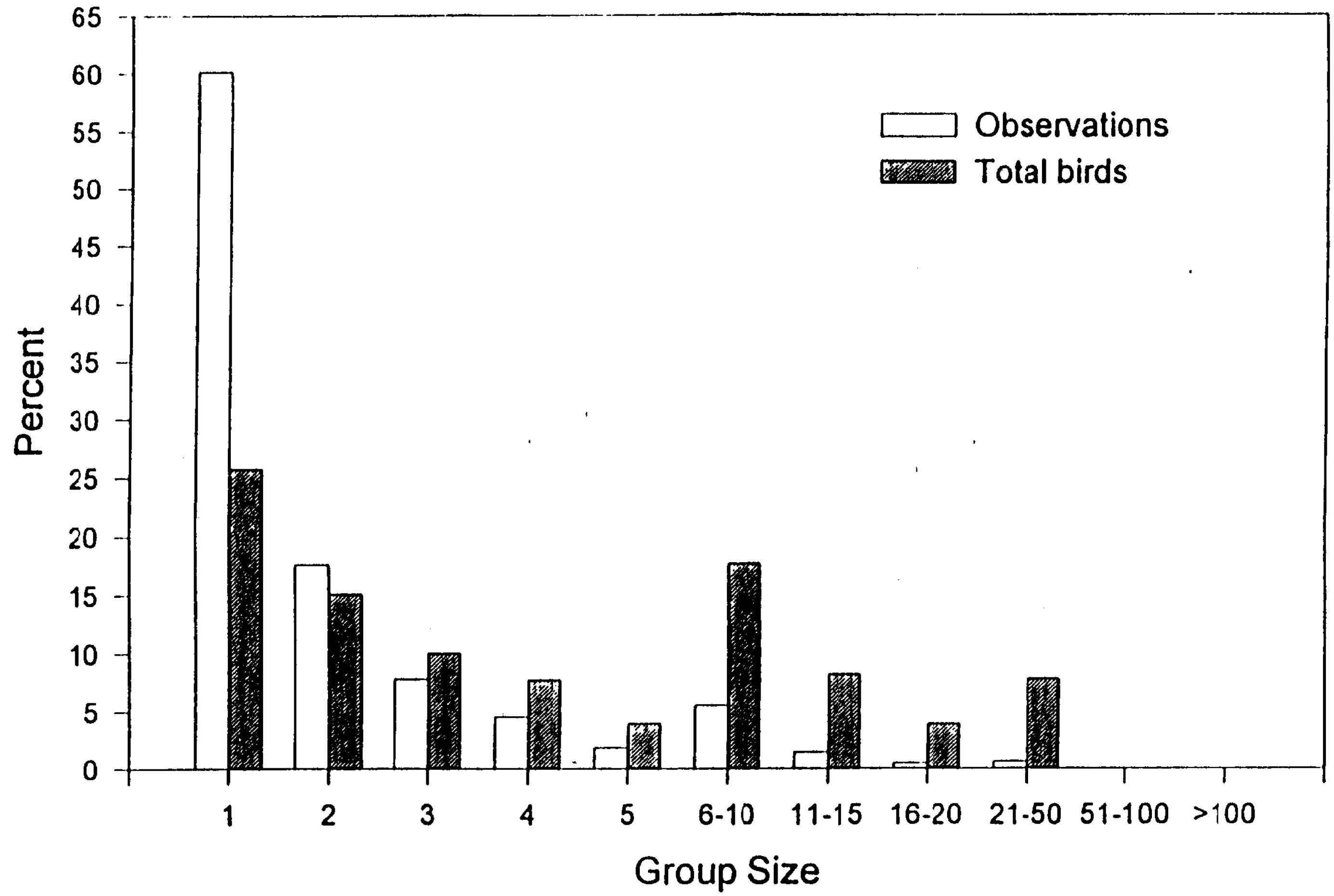
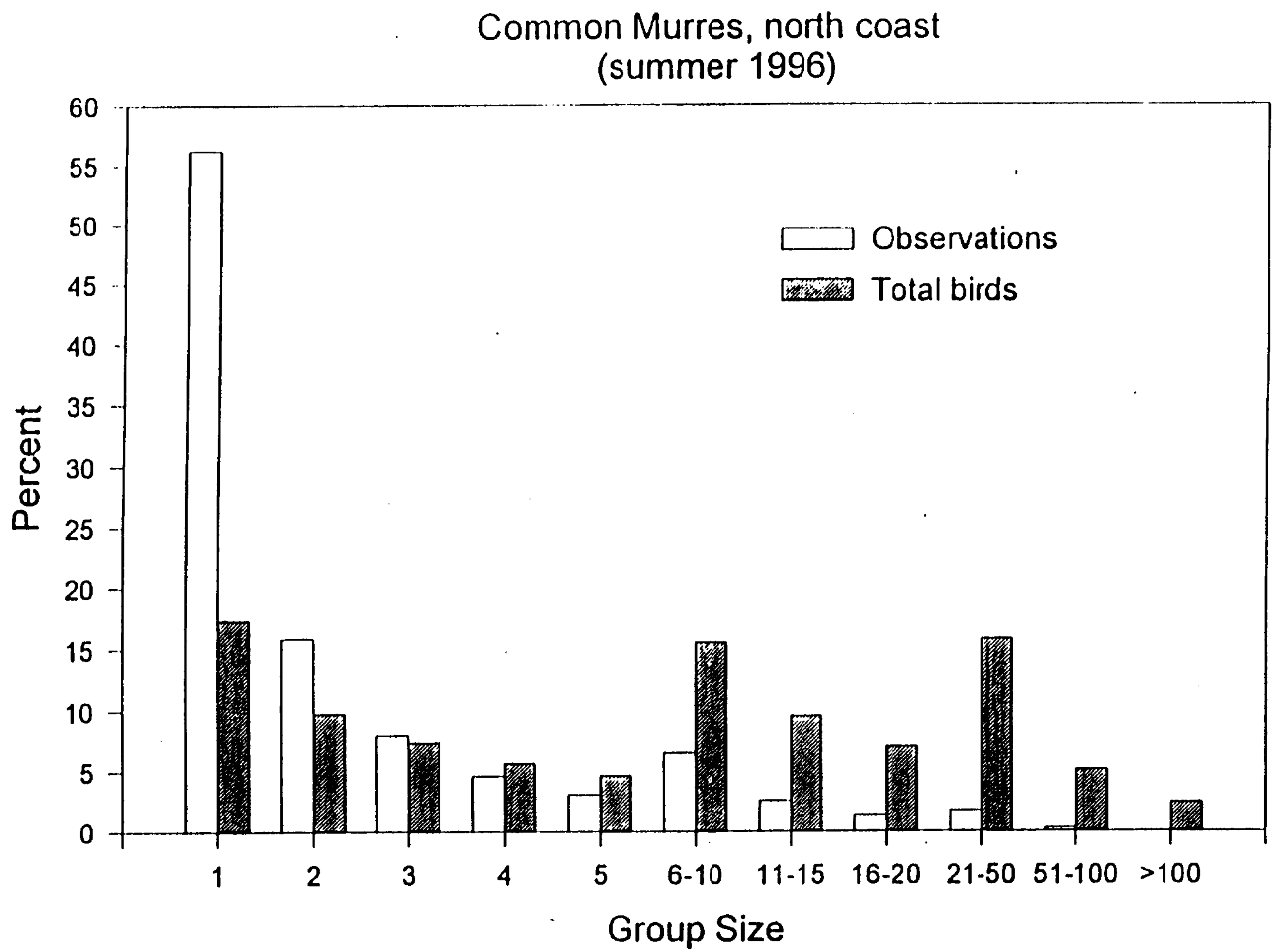


Figure 26

Figure 27


Common Murres, north coast
(summer 1996)
Percent
60
55
50
45
40
35
30
25
20
15
10
5
0
Observations
Total birds
1
2
3
4
5
6-10
11-15
16-20
21-50
51-100
>100
Group Size

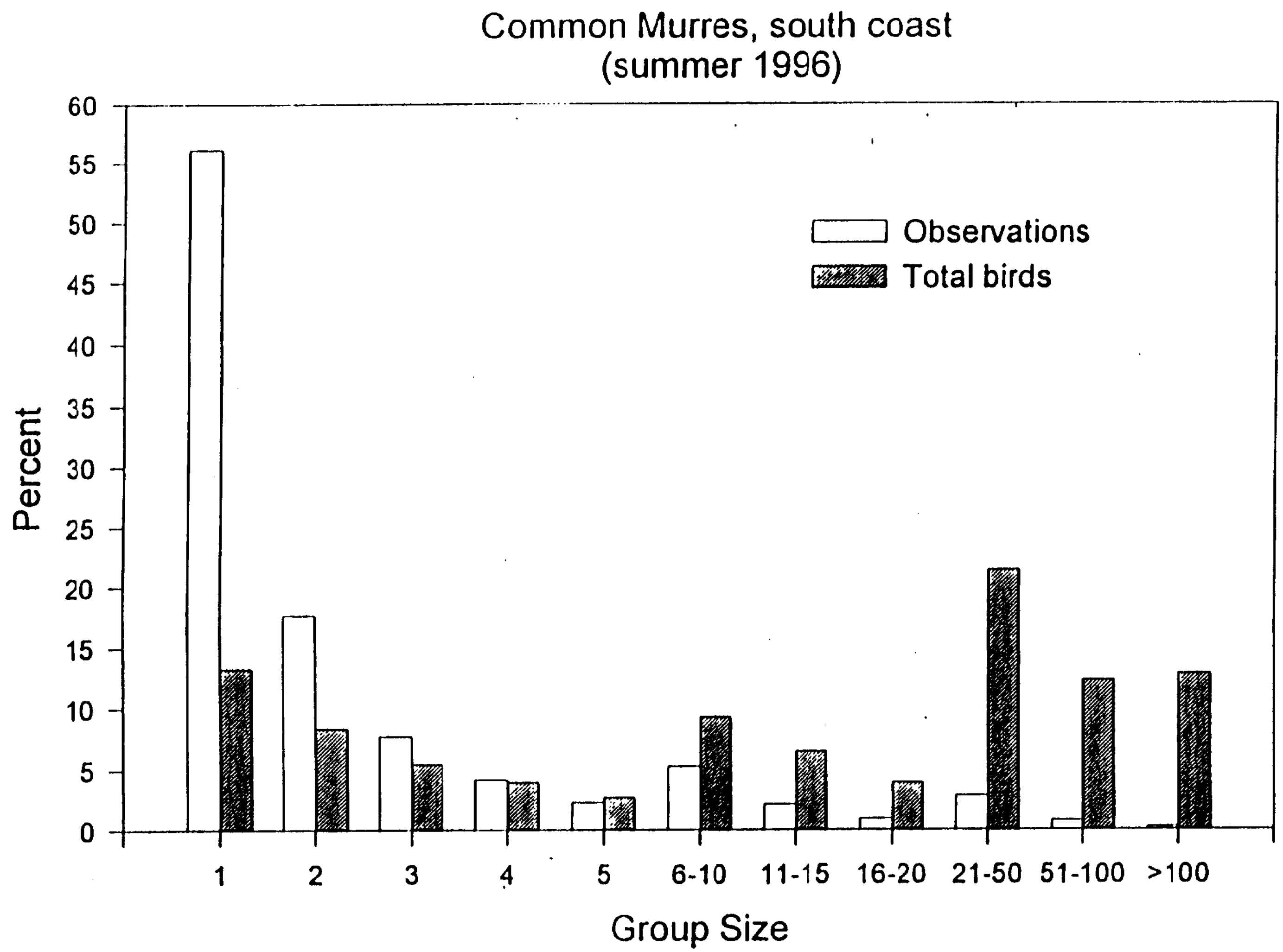

Common Murres, south coast
(summer 1996)
Observations
Total birds
Percent
60
55
50
45
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6-10
11-15
16-20
21-50
51-100
>100
Group Size

Figure 28

Figure 29

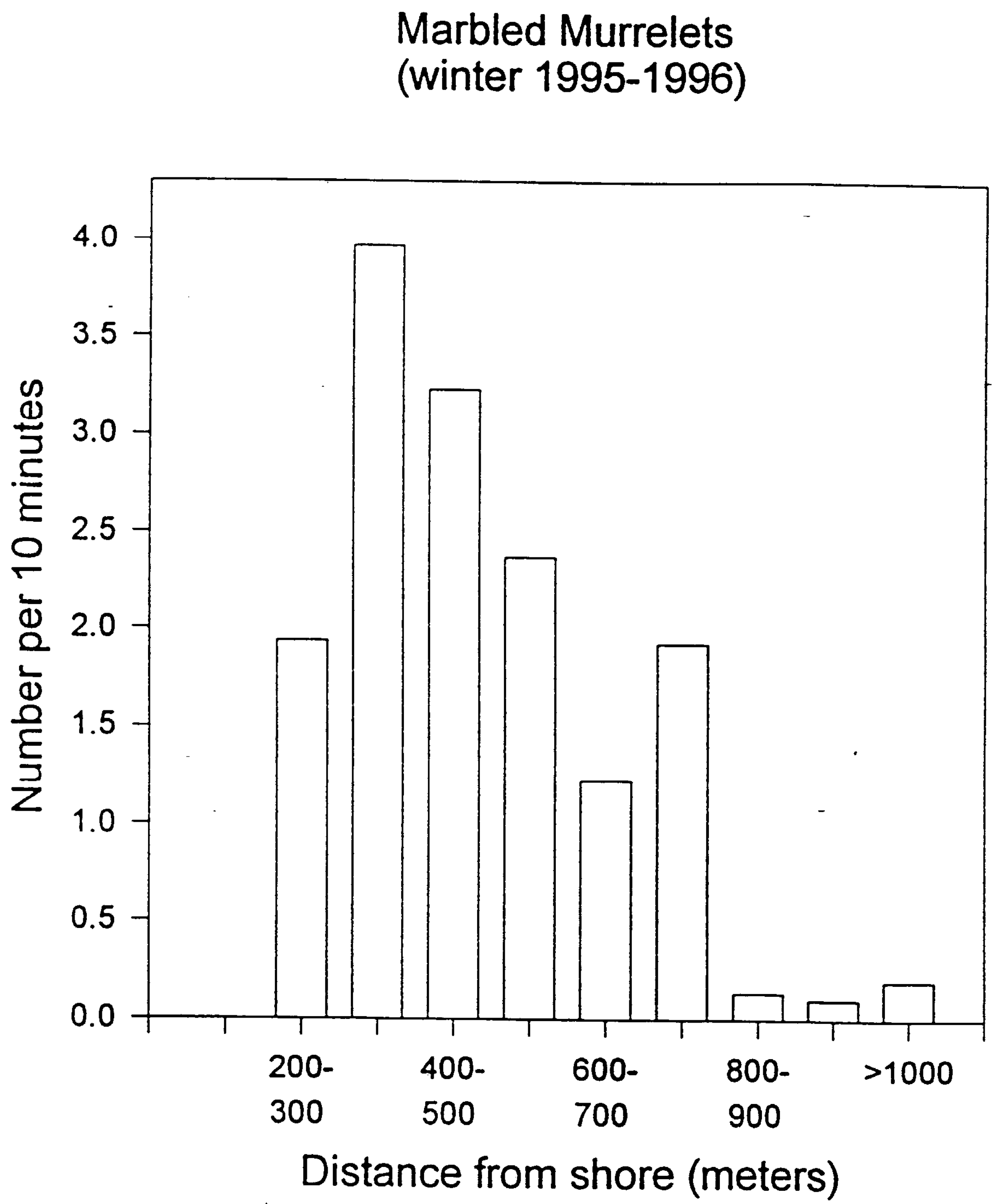
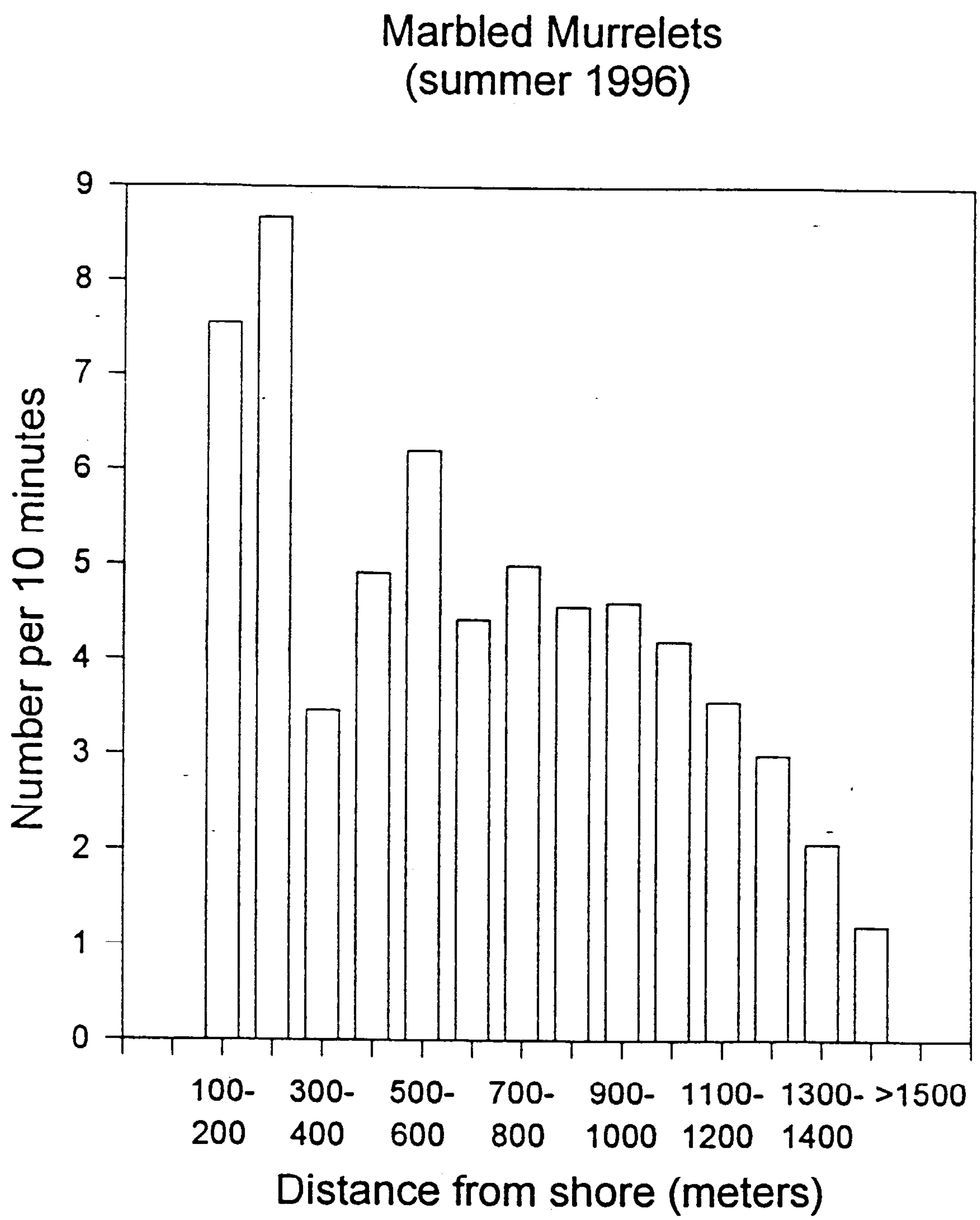

Marbled Murrelets
(winter 1995-1996)
Number per 10 minutes
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
200-
300
400-
500
600-
700
800-
900
>1000
Distance from shore (meters)

Figure 30



Marbled Murrelets
(summer 1996)
9
8
7
6
5
4
3
2
1
0
Number per 10 minutes
100-
200
300-
400
500-
600
700-
800
900-
1000
1100-
1200
1300-
1400
>1500
Distance from shore (meters)

Figure 31

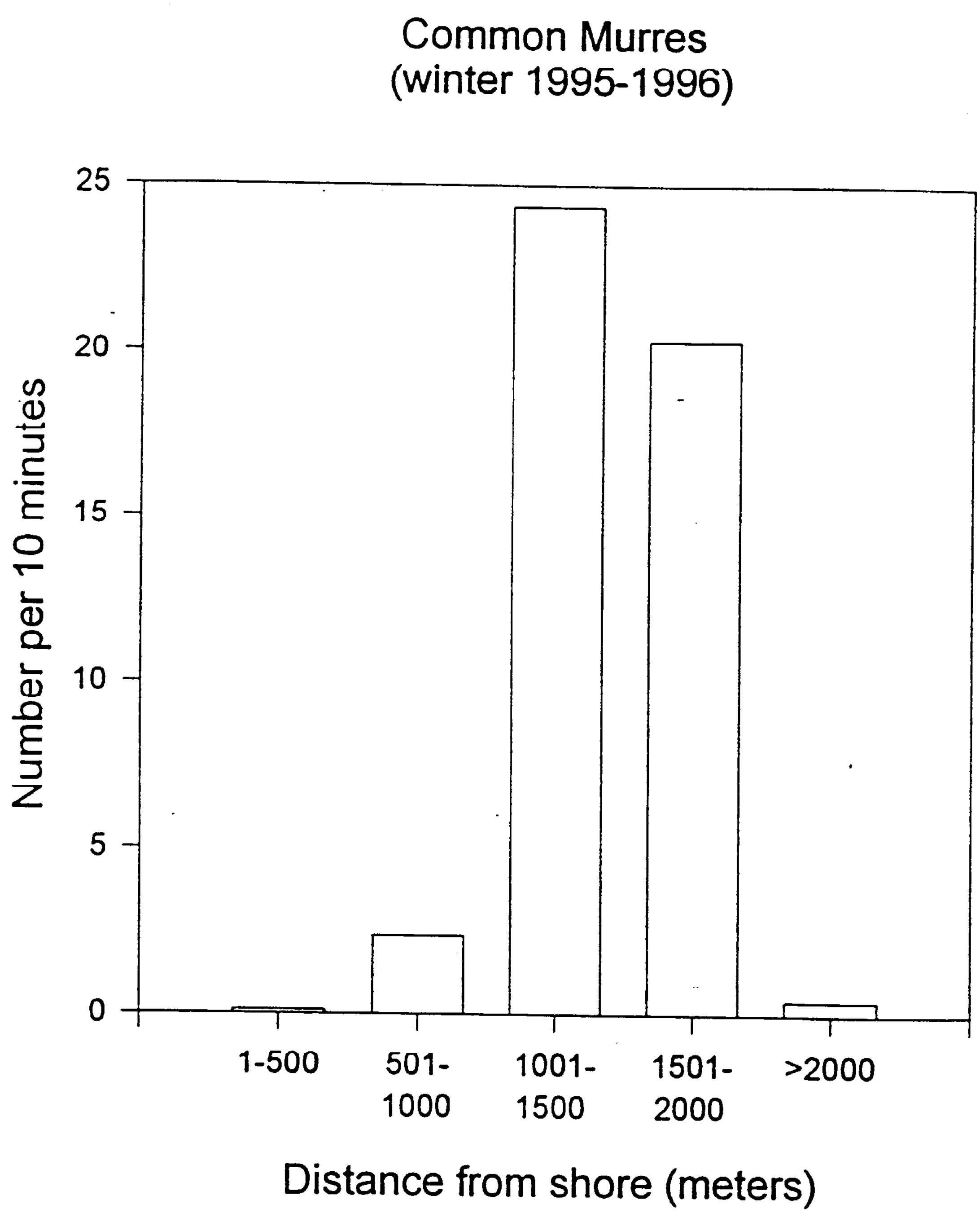

Common Murres
(winter 1995-1996)
25
20
15
10
5
0
Number per 10 minutes
1-500
501-
1000
1001-
1500
1501-
2000
>2000
Distance from shore (meters)

Figure 32

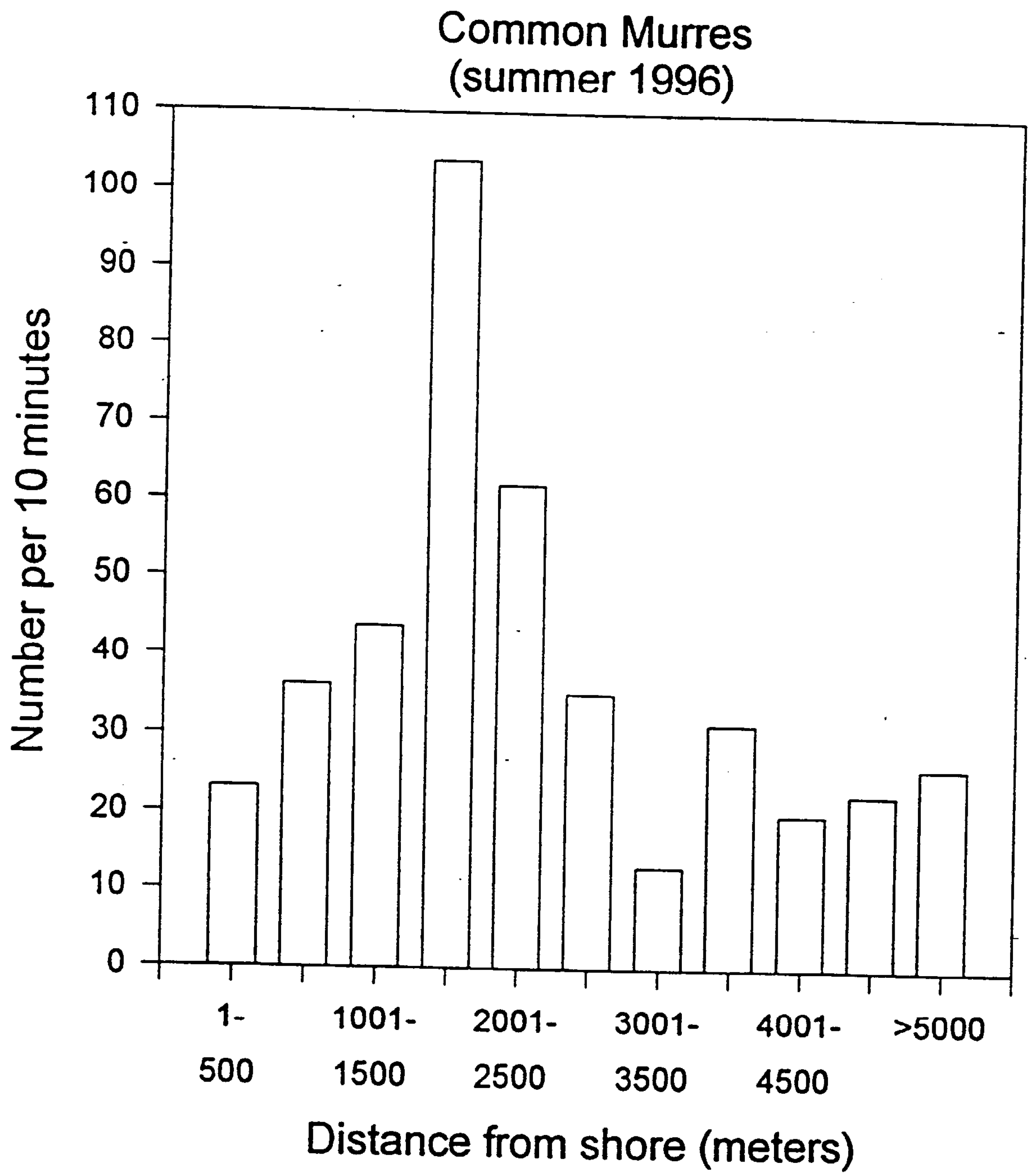

Common Murres
(summer 1996)
110
100
90
80
70
60
50
40
30
20
10
0
Number per 10 minutes
1-
500
1001-
1500
2001-
2500
3001-
3500
4001-
4500
>5000
Distance from shore (meters)

Figure 33

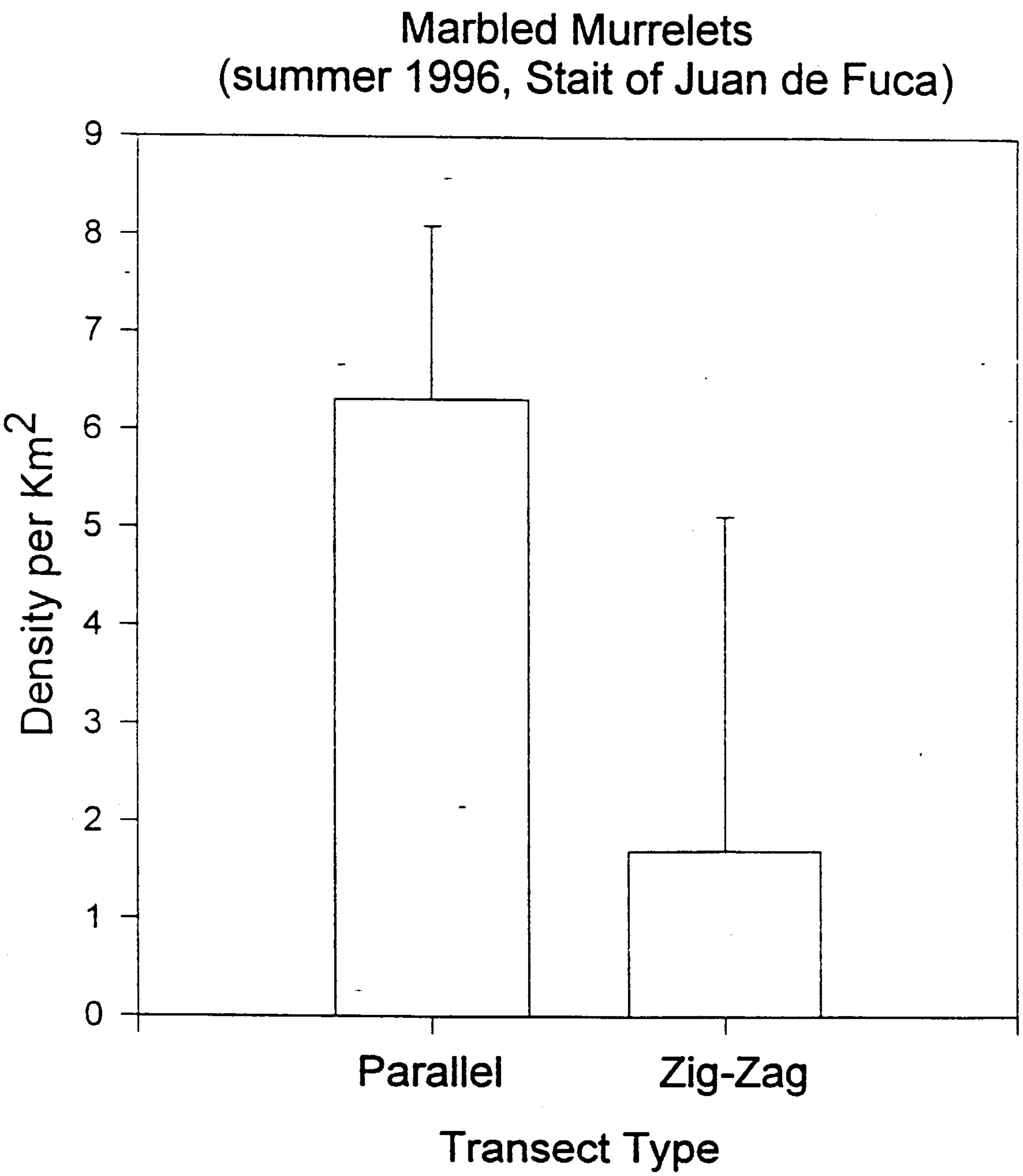

Marbled Murrelets
(summer 1996, Stait of Juan de Fuca)
9
8
7
6
5
4
3
2
1
0
Density per Km2
Parallel
Zig-Zag
Transect Type

Figure 34

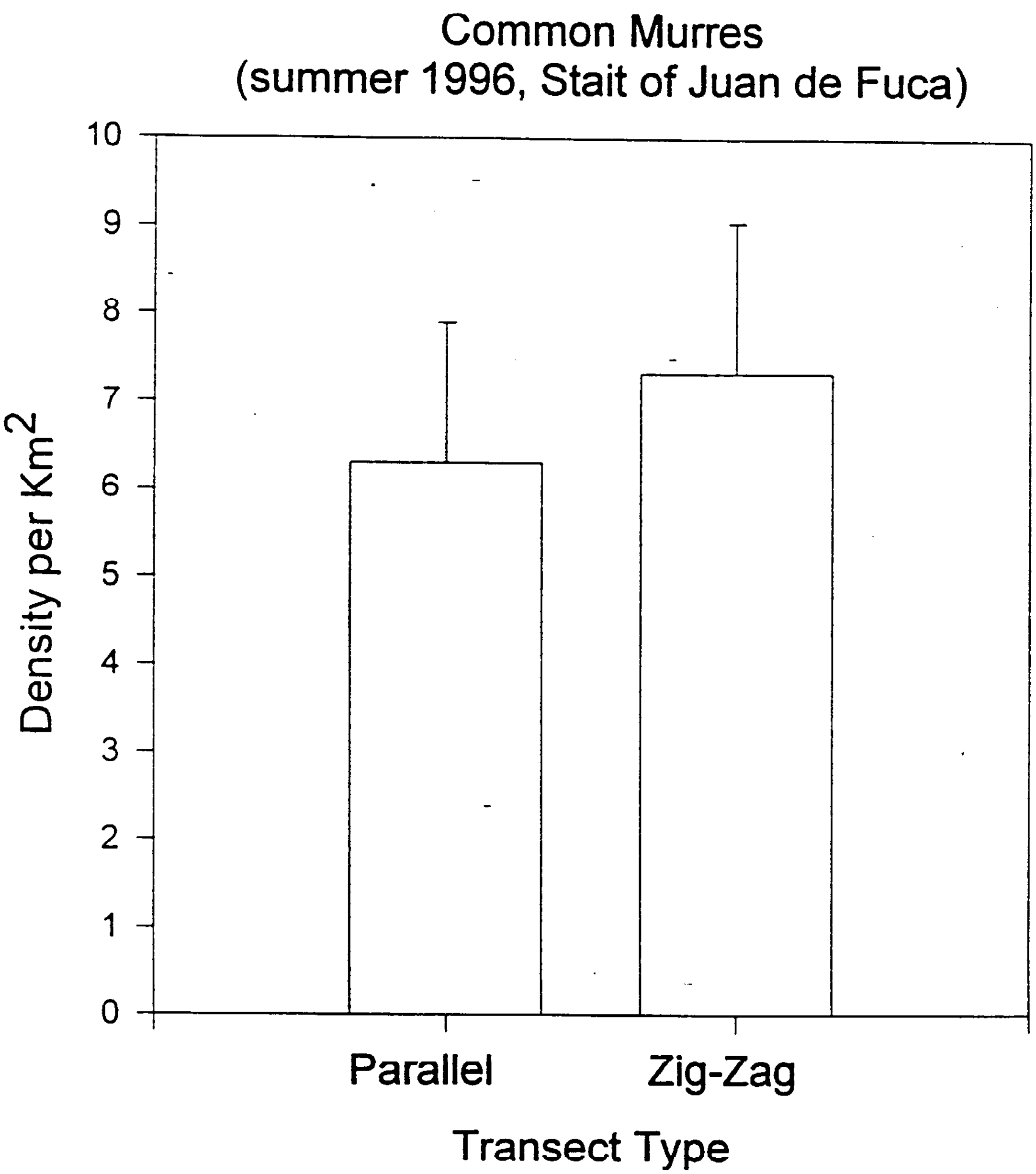

Common Murres
(summer 1996, Stait of Juan de Fuca)
10
9
8
7
6
5
4
3
2
1
0
Density per Km2
Parallel
Zig-Zag
Transect Type

Figure 35

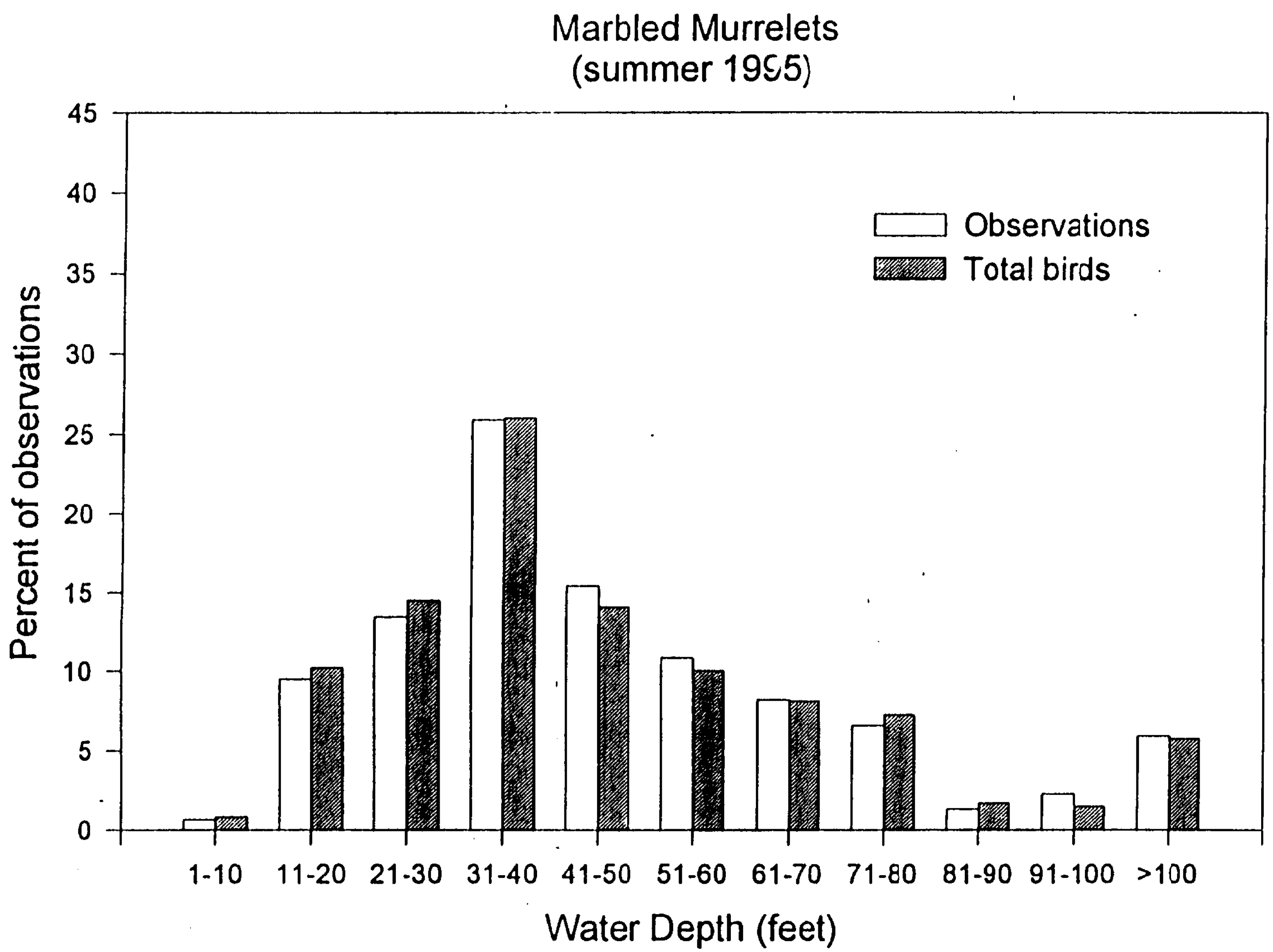

Marbled Murrelets
(summer 1995)
Percent of observations
45
40
35
30
25
20
15
10
5
0
Observations
Total birds
1-10
11-20
21-30
31-40
41-50
51-60
61-70
71-80
81-90
91-100
>100
Water Depth (feet)

Figure 36

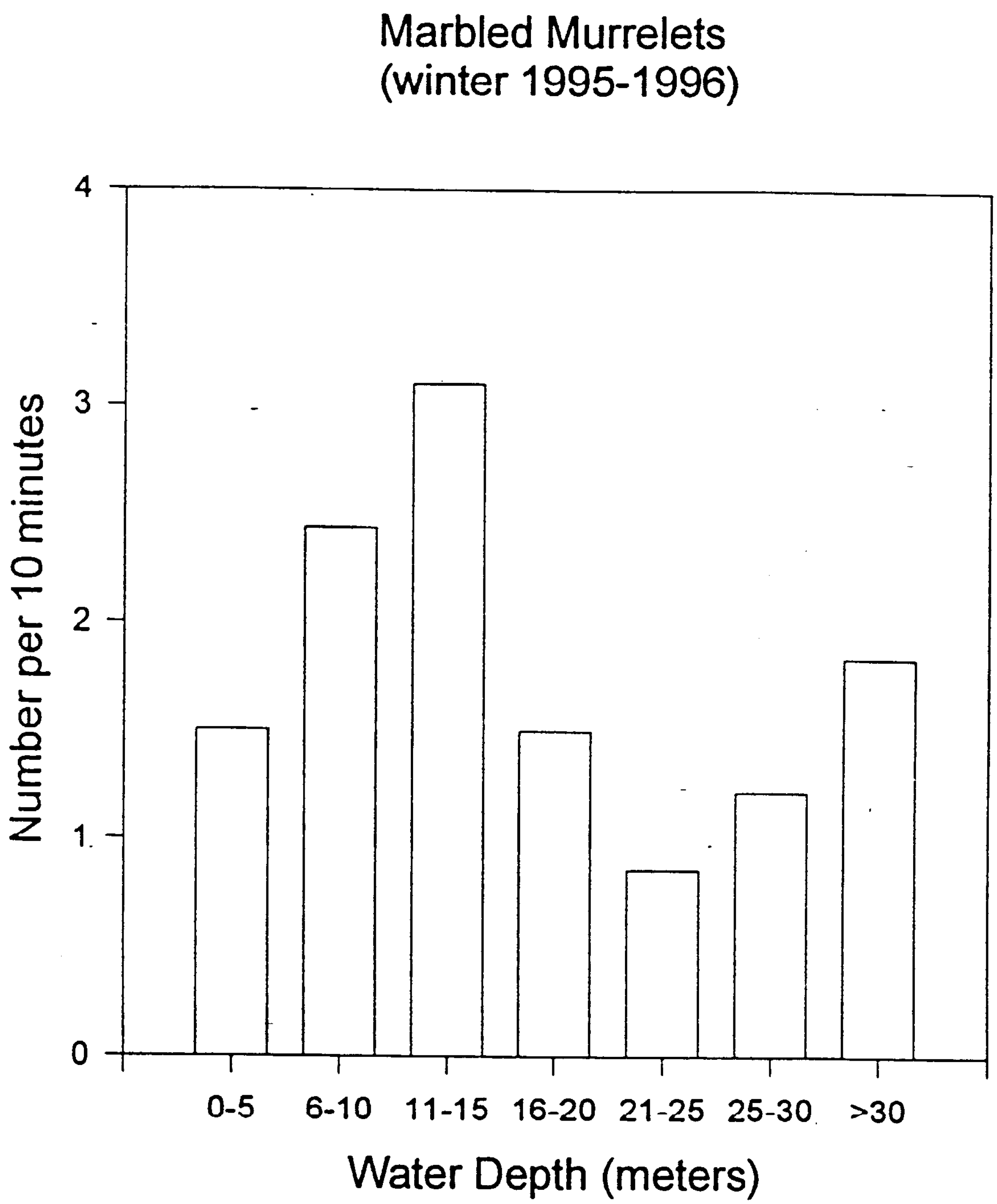

Marbled Murrelets
(winter 1995-1996)
4
3
2
1
0
Number per 10 minutes
0-5
6-10
11-15
16-20
21-25
25-30
>30
Water Depth (meters)

Figure 37

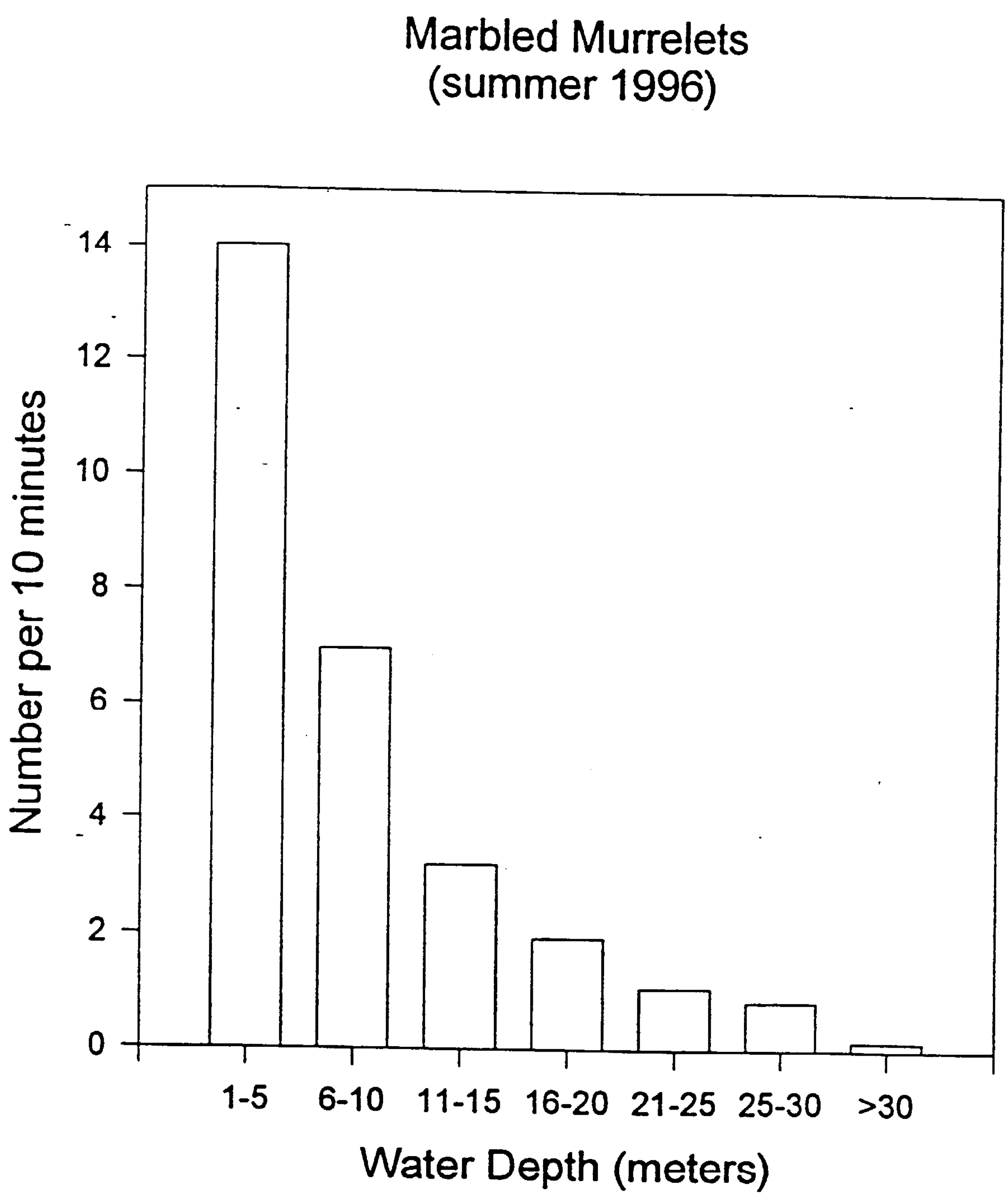
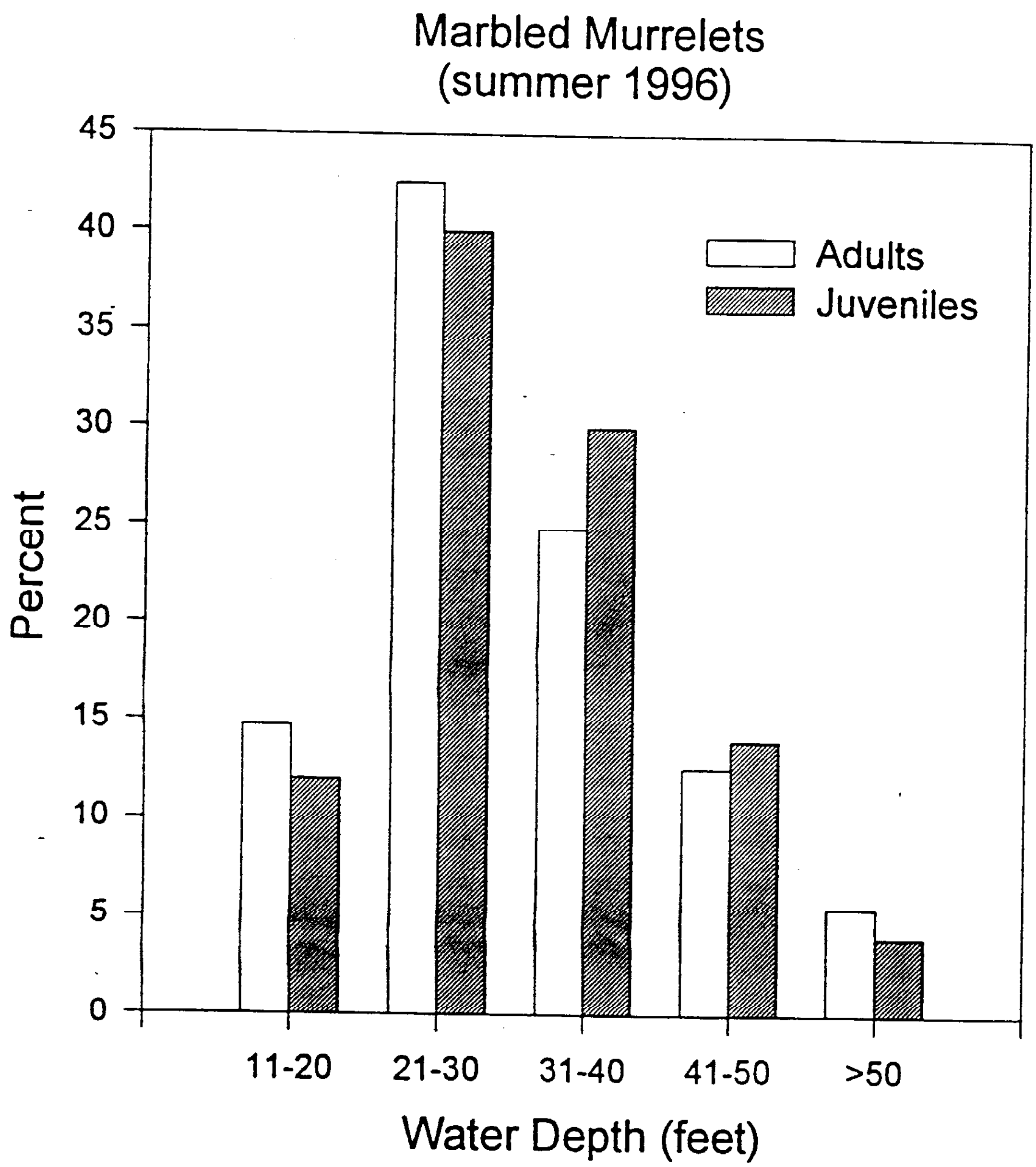

Marbled Murrelets
(summer 1996)
14
12
10
8
6
4
2
0
Number per 10 minutes
1-5
6-10
11-15
16-20
21-25
25-30
>30
Water Depth (meters)

Figure 38


Marbled Murrelets
(summer 1996)
45
40
35
30
25
20
15
10
5
0
Percent
Adults
Juveniles
11-20
21-30
31-40
41-50
>50
Water Depth (feet)

Common Murres
(winter 1995-1996)

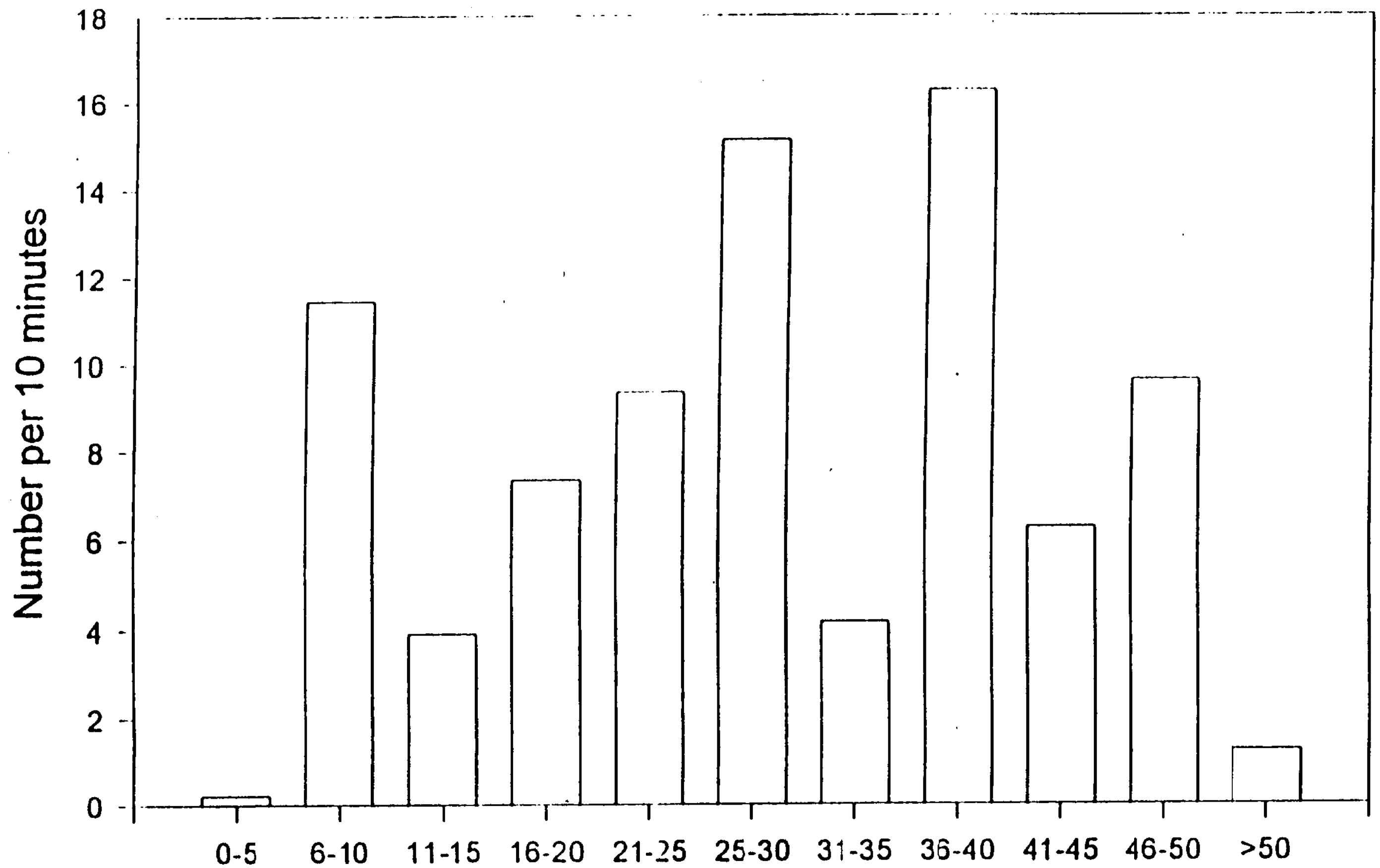


Figure 39

Figure 40

Common Murres
(summer 1996)

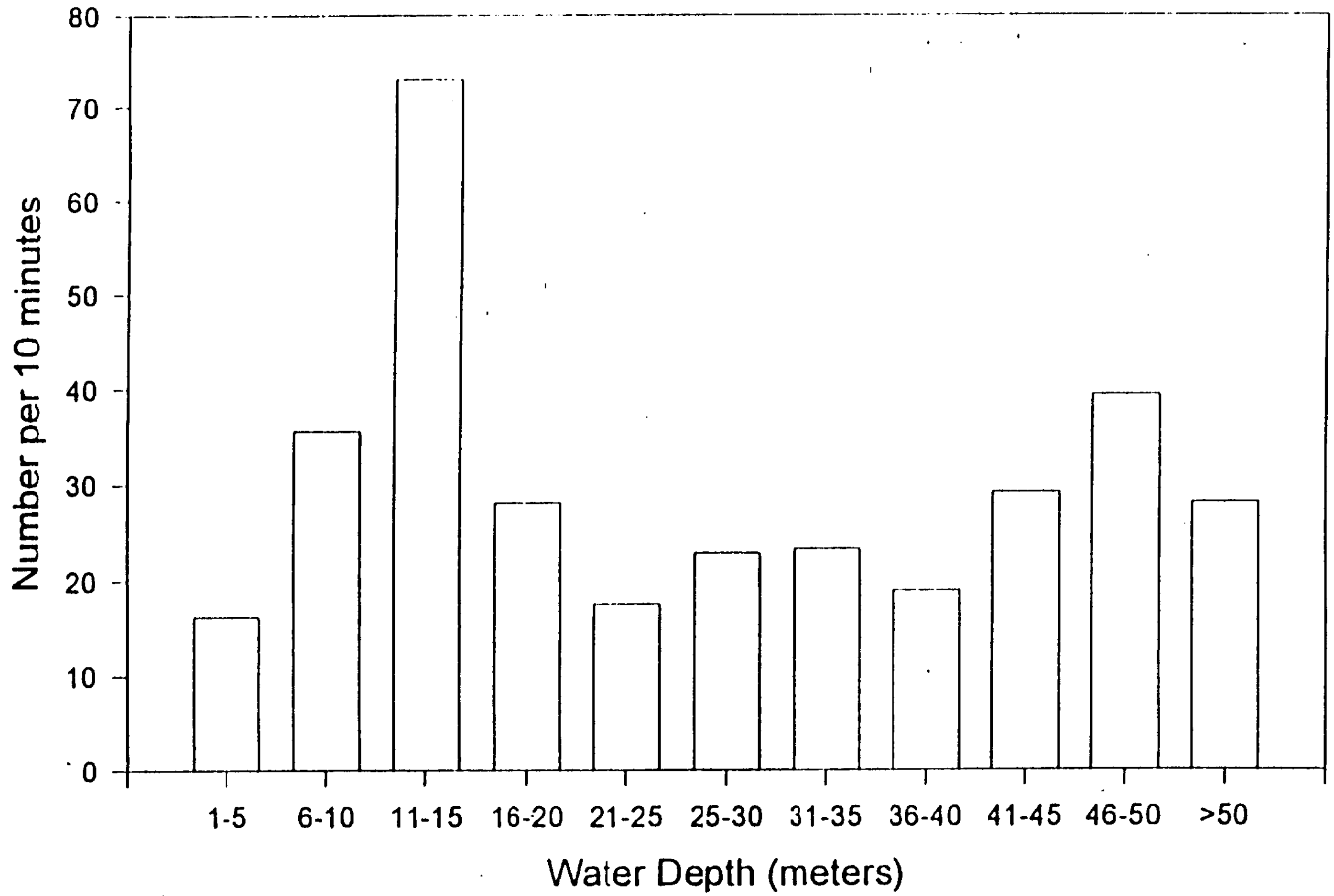
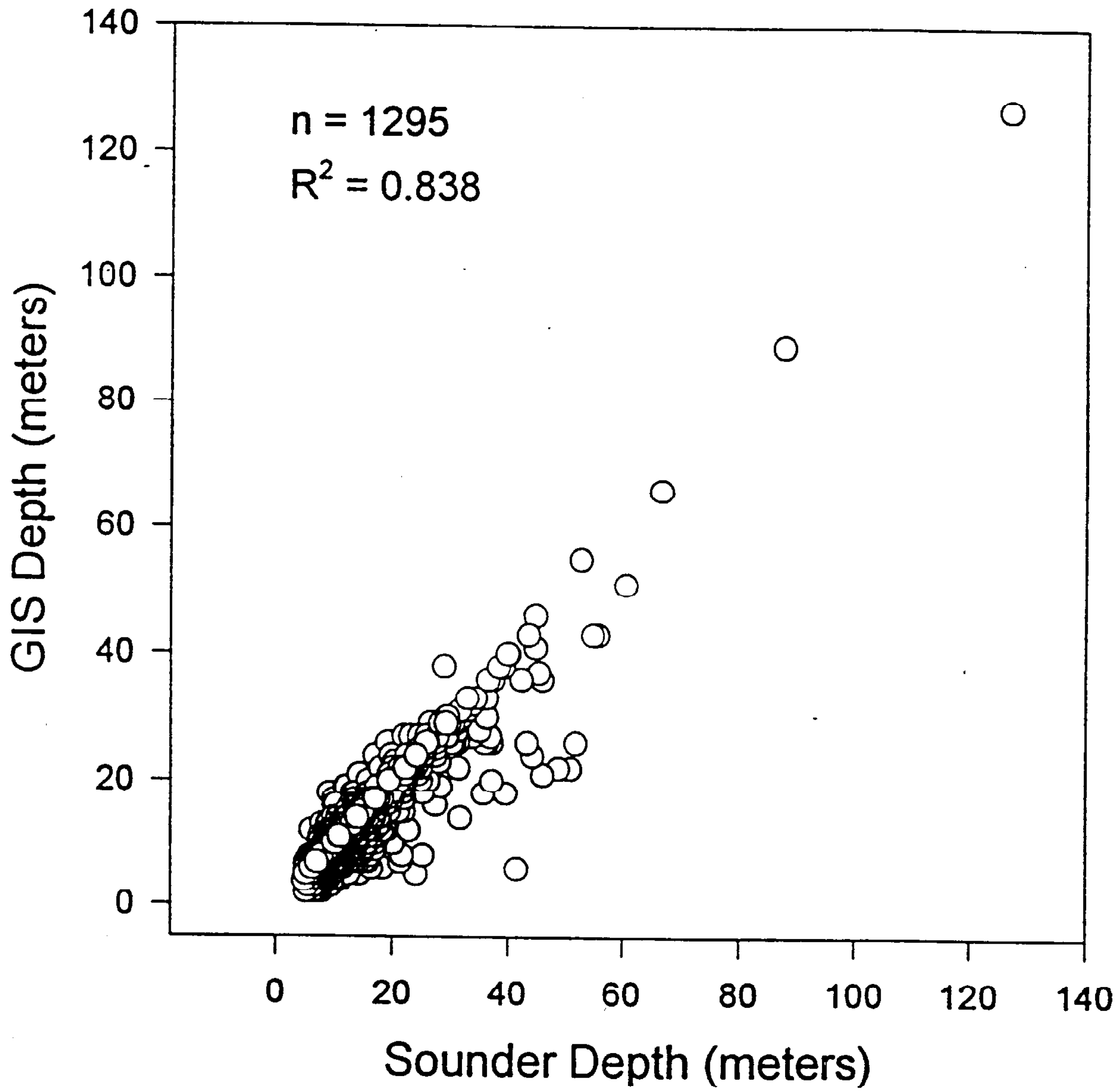


Figure 41



n = 1295
R2 = 0.838
GIS Depth (meters)
Sounder Depth (meters)
0
20
40
60
80
100
120
140

Figure 42

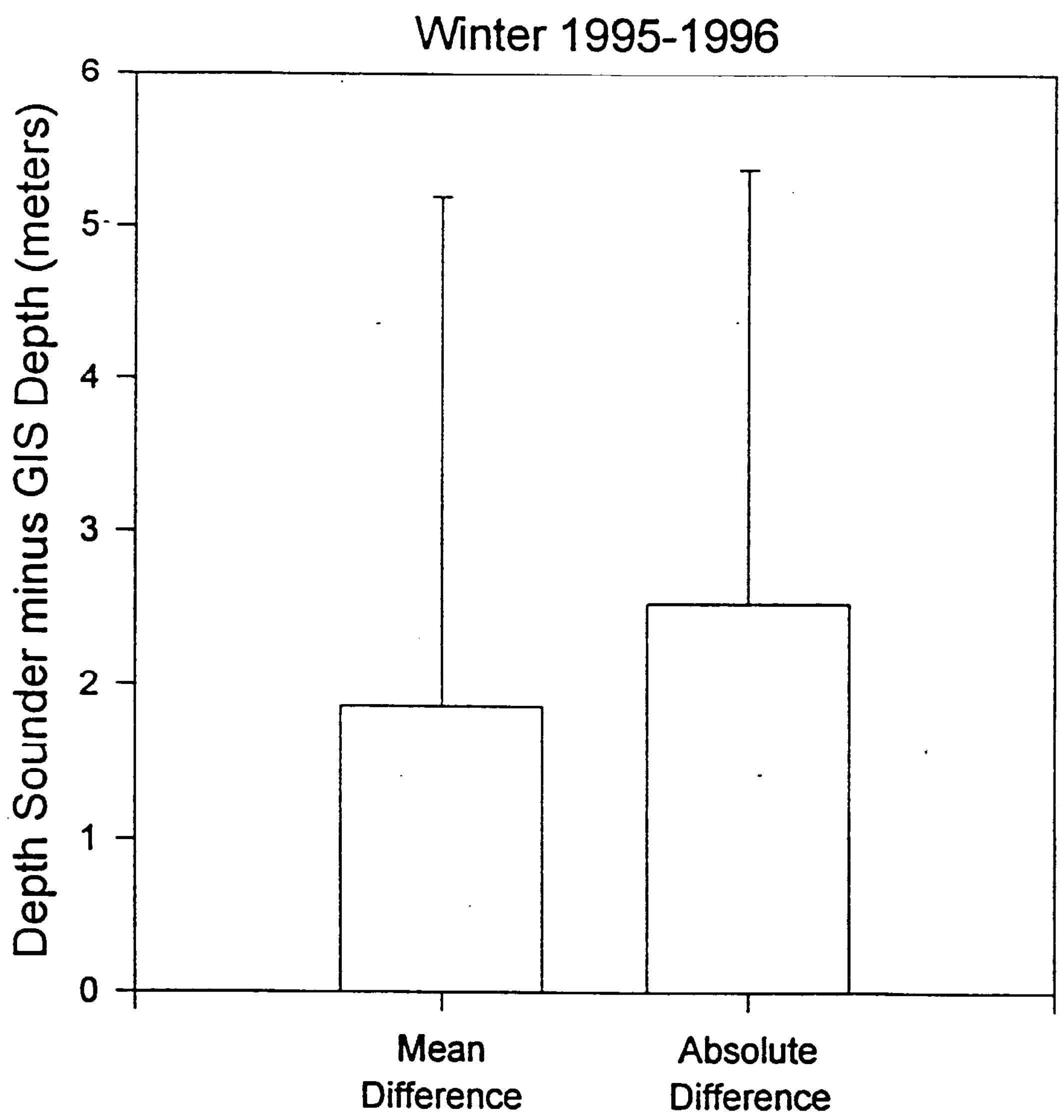
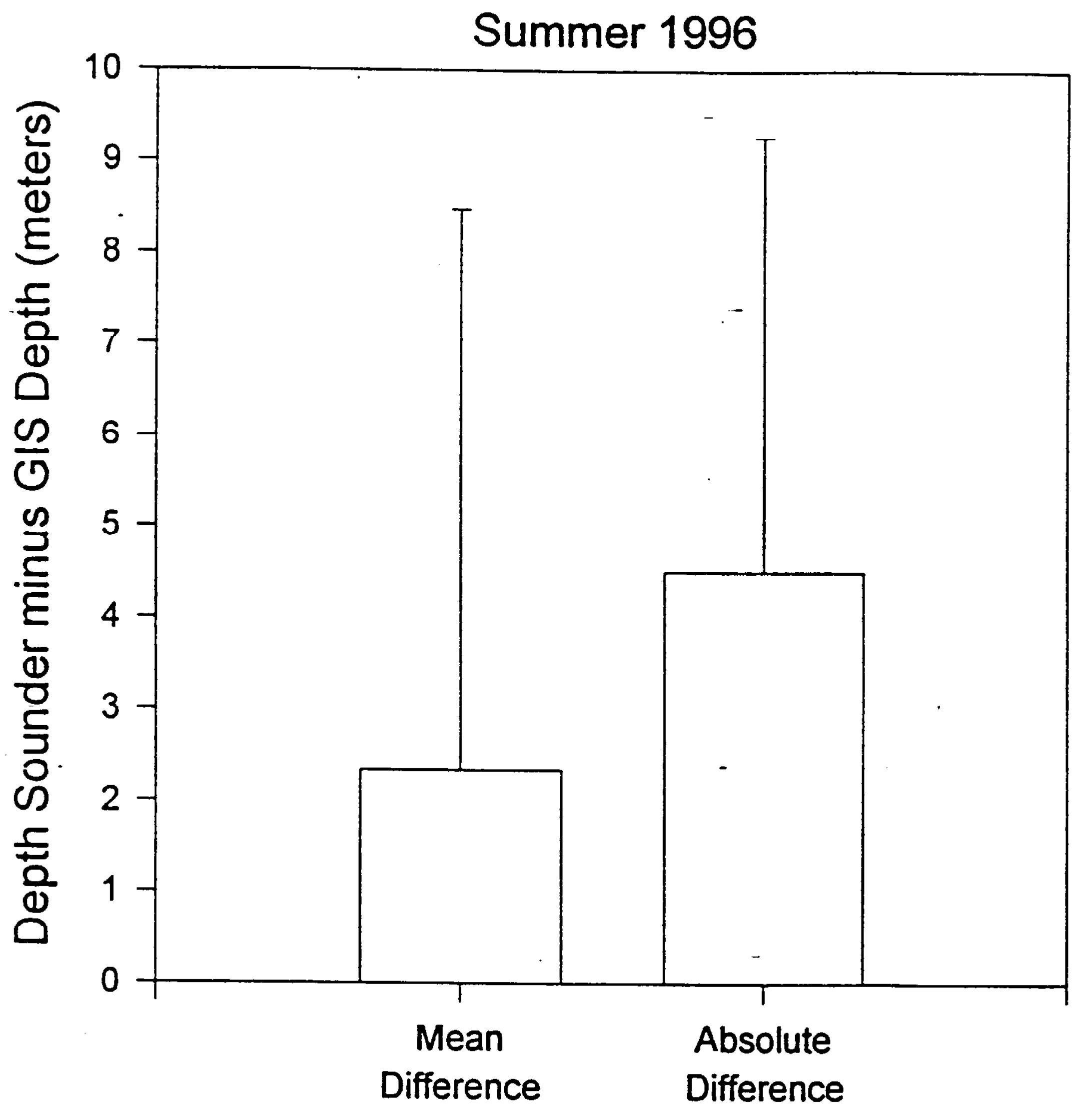

Winter 1995-1996
Depth Sounder minus GIS Depth (meters)
0
1
2
3
4
5
6
Mean Difference
Absolute Difference

Figure 43


Summer 1996
Depth Sounder minus GIS Depth (meters)
10
9
8
7
6
5
4
3
2
1
0
Mean Difference
Absolute Difference

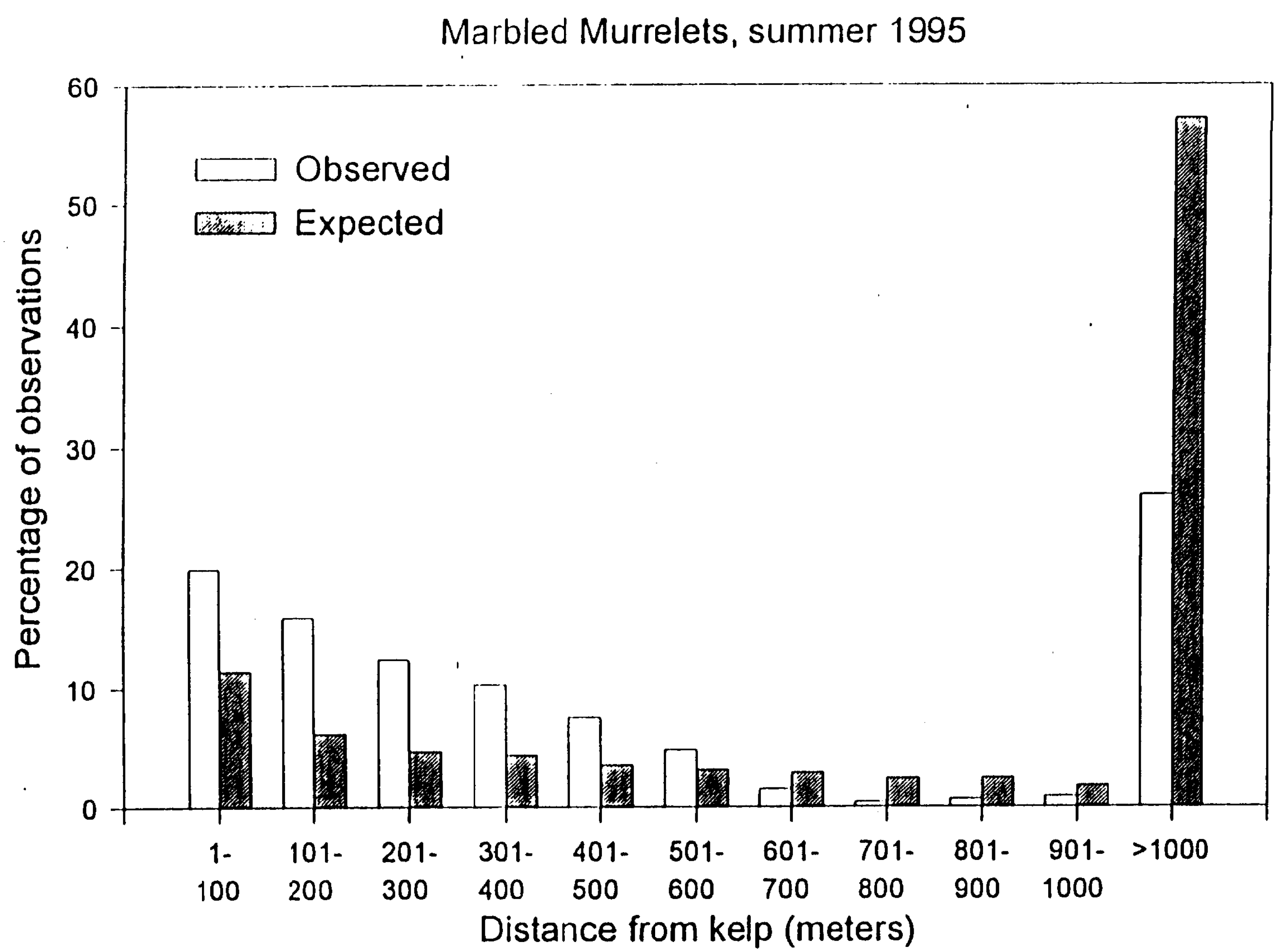

Marbled Murrelets, summer 1995
Observed
Expected
Percentage of observations
0
10
20
30
40
50
60
1- 100
101- 200
201- 300
301- 400
401- 500
501- 600
601- 700
701- 800
801- 900
901- 1000
>1000
Distance from kelp (meters)

Figure 44

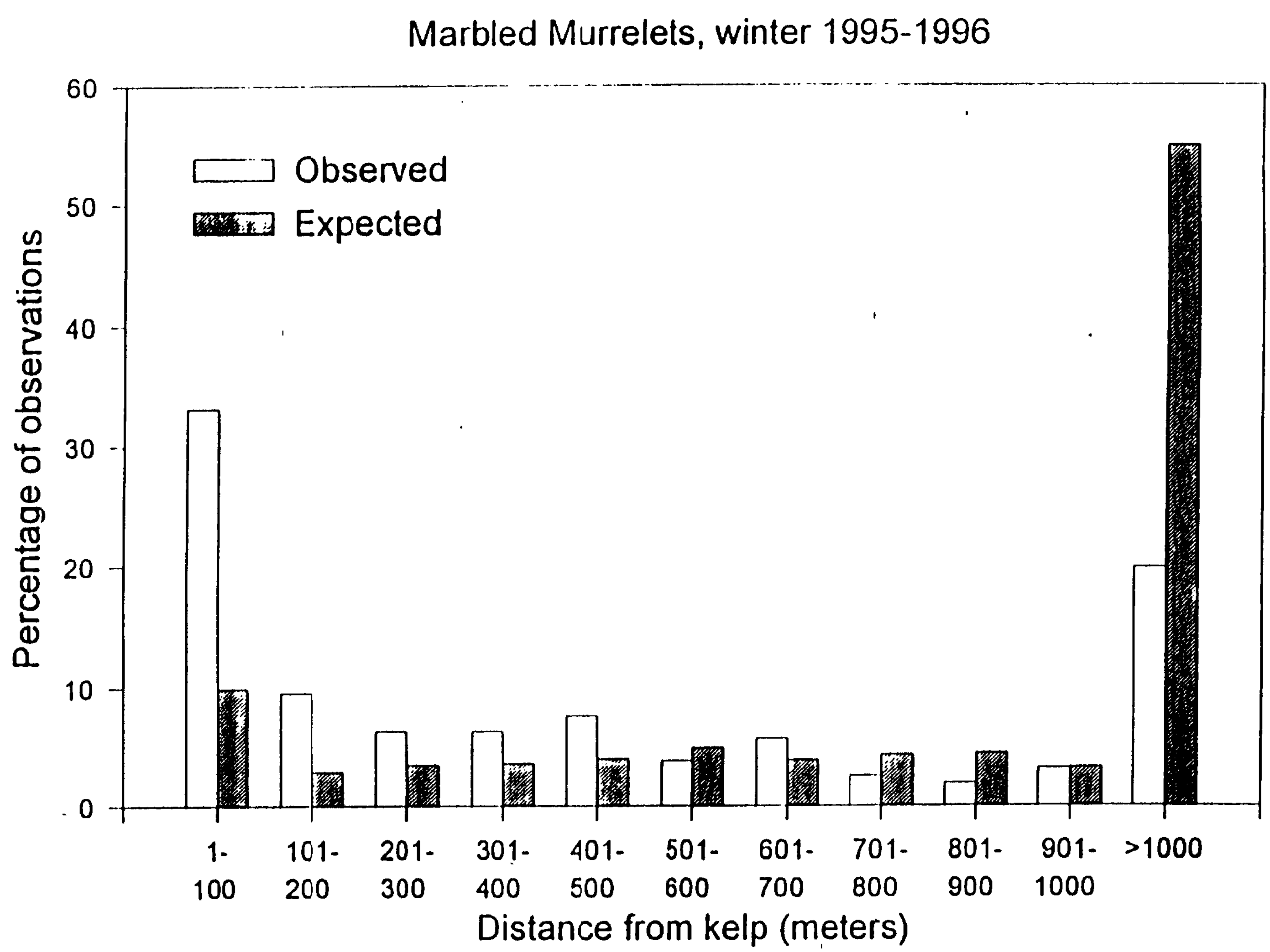
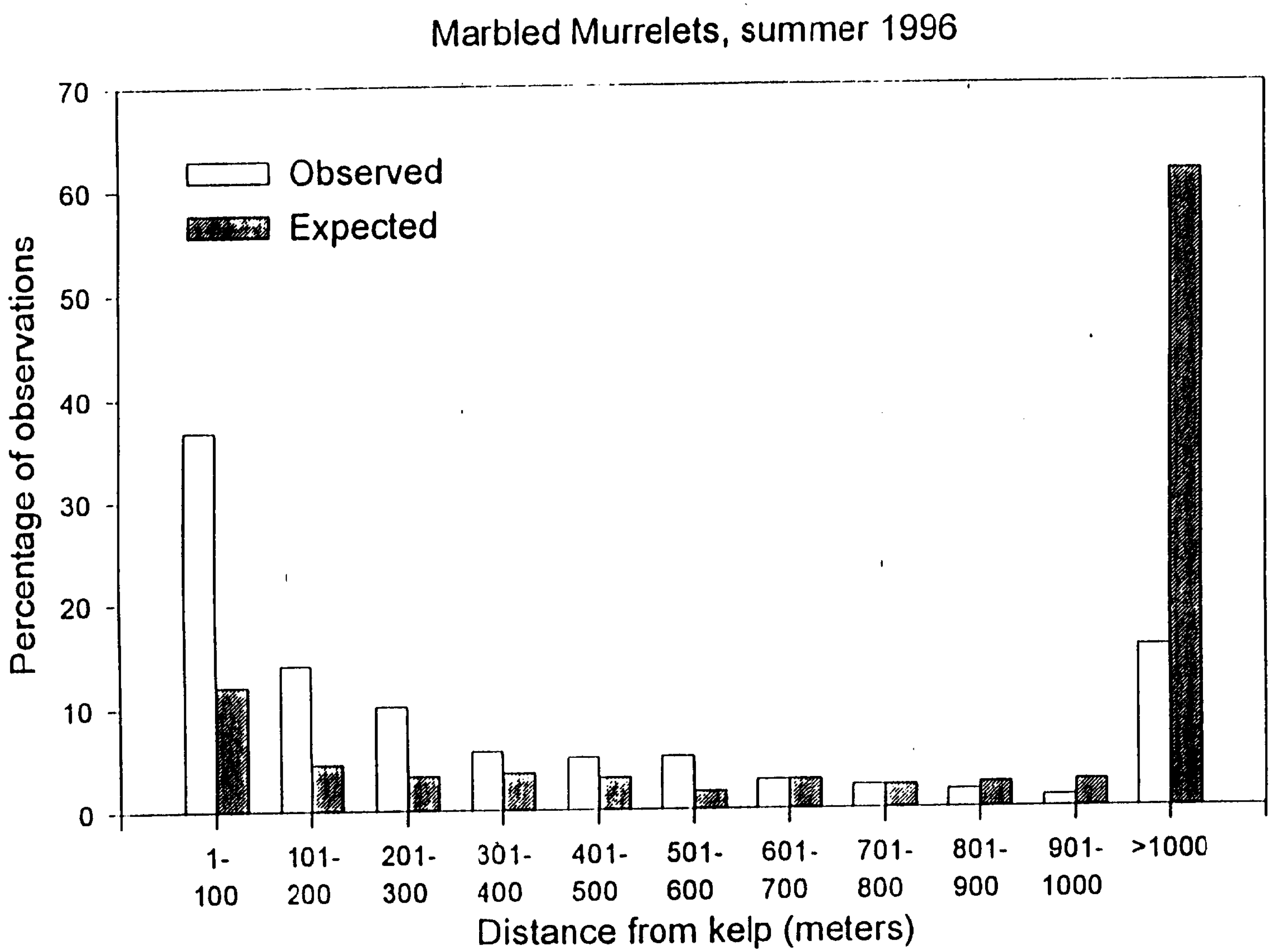

Marbled Murrelets, winter 1995-1996
Observed
Expected
Percentage of observations
60
50
40
30
20
10
0
1-
100
101-
200
201-
300
301-
400
401-
500
501-
600
601-
700
701-
800
801-
900
901-
1000
>1000
Distance from kelp (meters)

Figure 45



Marbled Murrelets, summer 1996
Observed
Expected
Percentage of observations
0
10
20
30
40
50
60
70
1-
100
101-
200
201-
300
301-
400
401-
500
501-
600
601-
700
701-
800
801-
900
901-
1000
>1000
Distance from kelp (meters)

Figure 46

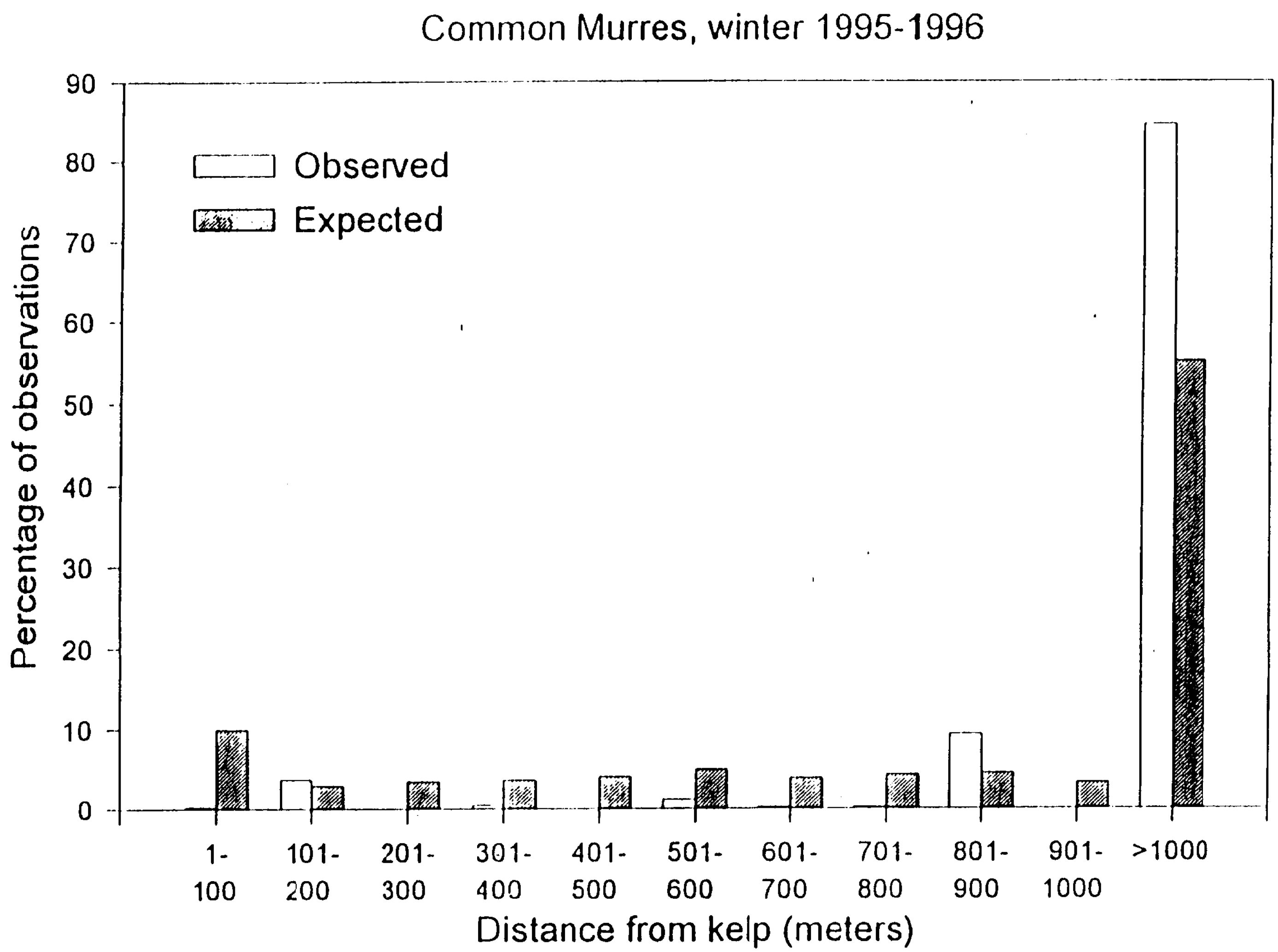

Common Murres, winter 1995-1996
Percentage of observations
90
80
70
60
50
40
30
20
10
0
Observed
Expected
1- 100
101- 200
201- 300
301- 400
401- 500
501- 600
601- 700
701- 800
801- 900
901- 1000
>1000
Distance from kelp (meters)

Figure 47

Figure 48

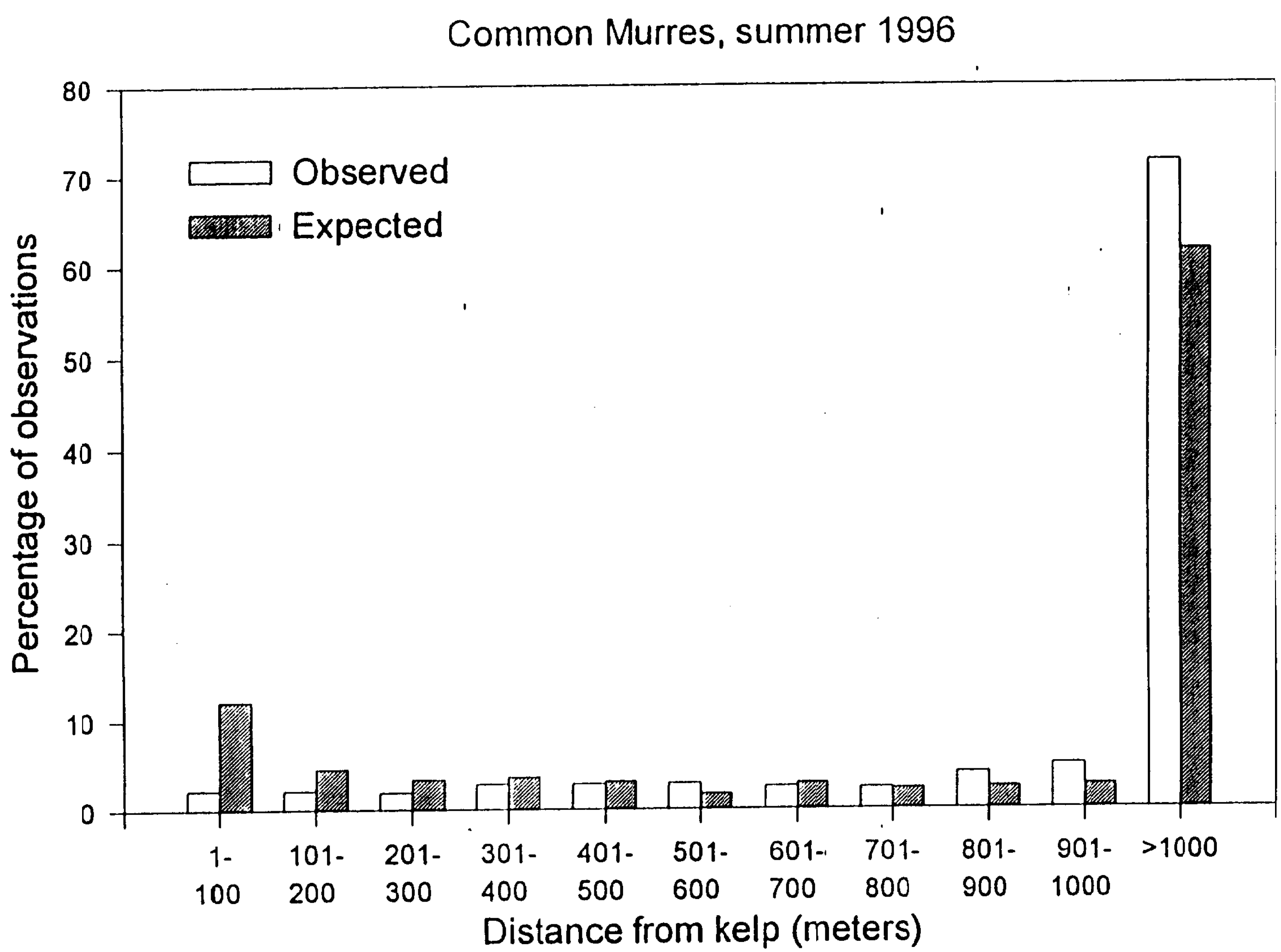
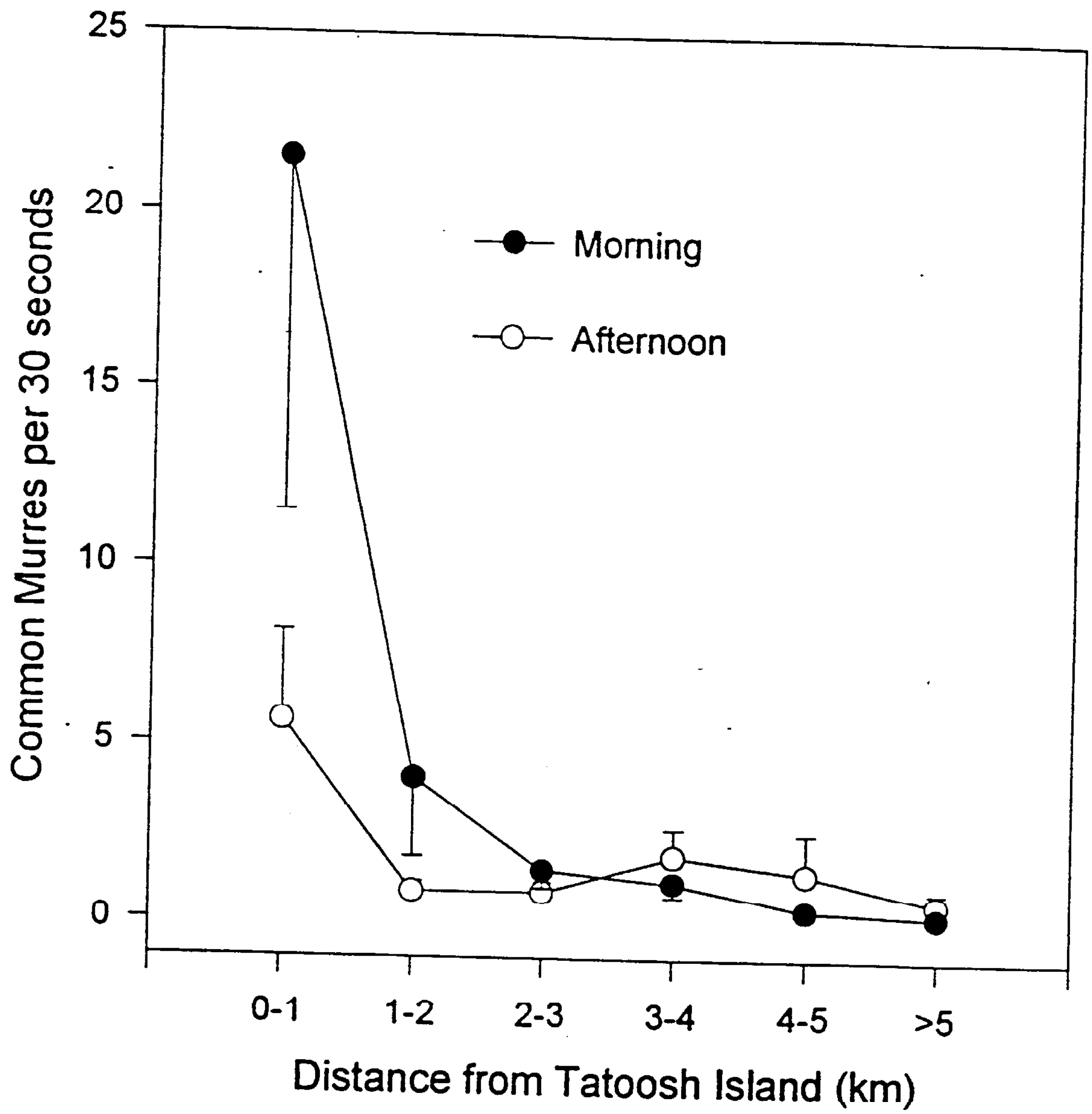
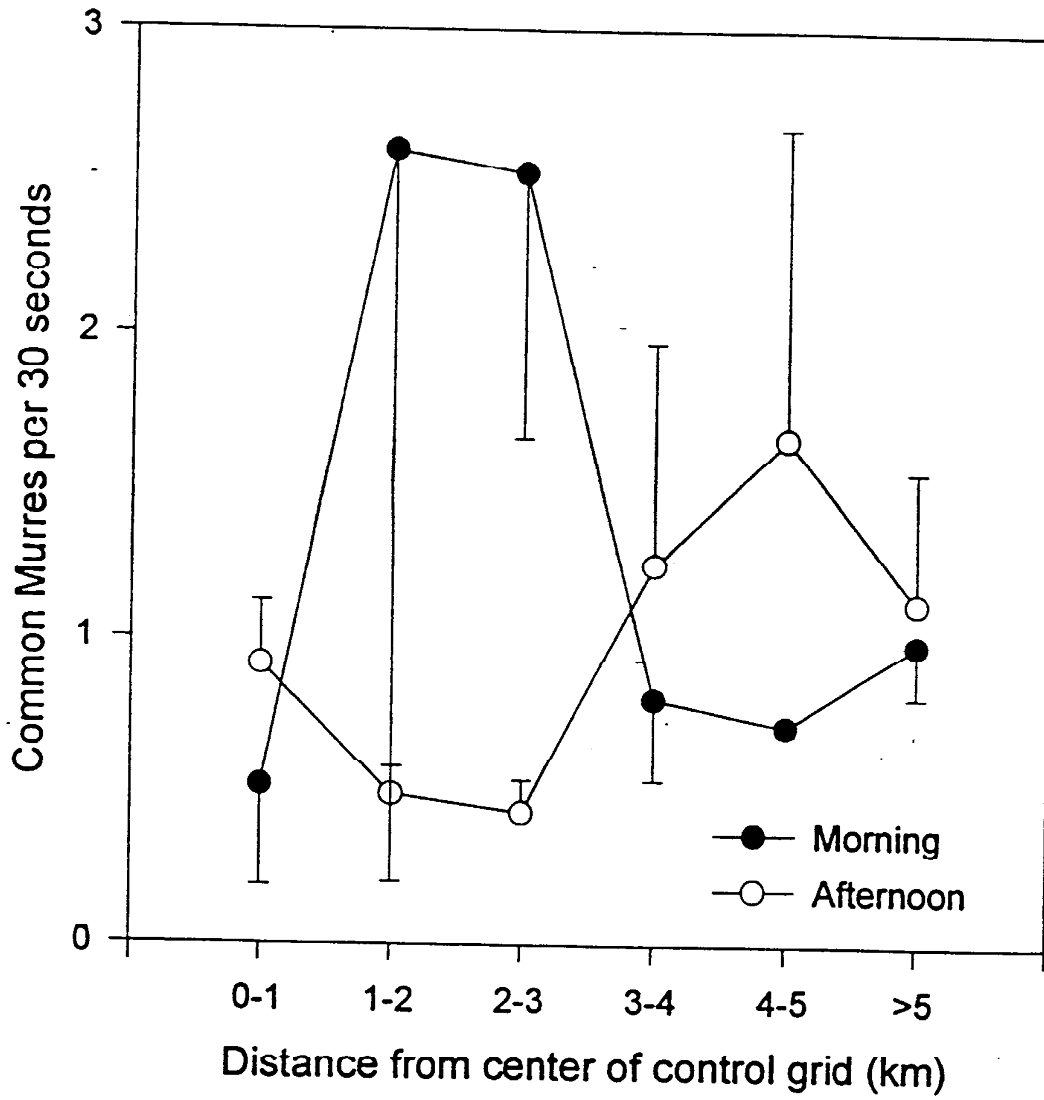

Common Murres, summer 1996
Observed
Expected
Percentage of observations
0
10
20
30
40
50
60
70
80
1- 100
101- 200
201- 300
301- 400
401- 500
501- 600
601- 700
701- 800
801- 900
901- 1000
>1000
Distance from kelp (meters)

Figure 49



25
20
15
10
5
0
Common Murres per 30 seconds
Morning
Afternoon
0-1
1-2
2-3
3-4
4-5
>5
Distance from Tatoosh Island (km)

Figure 50


3
2
1
0
Common Murres per 30 seconds
Morning
Afternoon
0-1
1-2
2-3
3-4
4-5
>5
Distance from center of control grid (km)