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Southeast Alaska Sea Cucumber Stock Assessment Surveys in 2010

by

Kyle Hebert

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Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY DATA REPORT NO. 10-88

SOUTHEAST ALASKA SEA CUCUMBER STOCK ASSESSMENT SURVEYS IN 2010

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ABSTRACT

The Alaska Department of Fish and Game drafted the first sea cucumber (*Parastichopus californicus)* fishery management plan prior to the fall commercial fishing season in 1990. The plan called for specific fishing areas to be opened to commercial fishing on a 3-year rotational basis, assessment surveys to be conducted prior to fishing, weekly fishing periods, and a number of control areas where commercial fishing would not be allowed. Assessment surveys are conducted using SCUBA diving to count sea cucumbers on 2-meter wide transects, and collect samples for estimates of average weight. During the 2010 survey season, a total of 514 transects were completed during 24 sea cucumber population assessment surveys conducted in commercial fishery areas in Southeast Alaska. These areas represent approximately one-third of the sea cucumber commercial fishery areas in the region, which are surveyed triennially. An additional 106 transects were completed during surveys in 5 different control areas that are closed to commercial harvest. Some of the commercial fishing areas have been surveyed up to 7 times, providing a time series to follow trends in density, weight, and biomass. Other areas, usually those with the lowest densities of sea cucumbers, have been surveyed on only one occasion. In 2009, the highest biomass of sea cucumbers was found in Subdistricts 106-10, 20, and 22 at 1,215,312 pounds (554,182 kg), and the lowest biomass was found in Subdistricts 110-31, 32, 33, and 34, at 116,505 pounds (53,126 kg).

Key words: sea cucumber, *Parastichopus californicus*, Southeast Alaska, dive surveys, stock assessment, fishery

INTRODUCTION

The commercial sea cucumber *Parastichopus californicus* fishery expanded rapidly in the late 1980s and in 1989 the fishery exceeded the ability of the department to manage by a permit system. The department closed the fishery in May 1990 and reopened it in October 1990 following development of the Southeast Alaska Sea Cucumber Commercial Fisheries Management Plan (5 AAC 38.140). This management plan was initially developed in 1990 (ADF&G 1990) and adopted into regulations (5 AAC 38.140.) by the Alaska Board of Fisheries (ADF&G 1991, 1992). The management plan is based on a conservative policy of sustained yield (Woodby et al. 1993) and seeks both to protect subsistence opportunities and provide for sustained commercial fishing harvests. To protect subsistence opportunities, the cucumber management plan established 18 areas closed to commercial fishing (5 AAC 38.140 (k)). There are also provisions to prevent the use of diving gear in the subsistence (5 AAC 02.020 (1)) and personal use (5 AAC 77.010 (l)(3)) fisheries in those areas.

This document describes population assessment surveys and results for sea cucumber surveys in Southeast Alaska during the 2010 survey season, and additionally includes result from surveys conducted in 1992, 1995, 1998, 2001, 2004, 2007 seasons. The intent is to characterize the current status of sea cucumber stocks relative to trends observed for areas in this fishery rotation (henceforth called the 1992/2010 rotation). Surveys conducted during 2010 represent approximately one-third of all commercial fishery areas in Southeast Alaska. The overall goals of the sea cucumber stock assessment survey program are to estimate the total number and average weight of sea cucumbers in both commercial harvest areas, and control areas (areas closed to commercial harvest), and to establish a biologically acceptable harvest level for areas opened to commercial fishing.

Fishing areas are opened on a 3-year rotational basis. The rationale for rotational fisheries in this instance is to reduce costs: survey and management costs are incurred only once every 3 years for any fished area. The rotational system was not implemented to allow an area to rest between harvests. Rotational harvest was considered unnecessary because harvest biomass is limited by a conservative exploitation rate approach (Larson et al. 2001a). Annual commercial fishery guideline harvest levels are calculated as the product of the lower 90% confidence limit on the biomass estimate and the annual target exploitation rate of 0.064, multiplied by 3 to adjust for triennial harvest. This results in a harvest rate of about 19.2% every 3 years. However, because the lower bound confidence limit is used, it is likely that the effective harvest rate is below this. Other aspects of the survey provide added conservative measures. These include surveys restricted to 50 ft (mean lower low water) of depth even though sea cucumbers are observed deeper, and, probable minimum sea cucumber counts along transects, due to limitations from kelp coverage and underwater visibility.

Although estimates of biomass and the harvest rate for sea cucumbers are considered to be conservative, there is currently not a control rule in the management plan designed to trigger a reduction in harvest rate or fishery closure. Trends in density, average weight, and biomass are considered when making decisions about commercial fishery openings; however the ability to accurately target a guideline harvest level based on expected fishing effort has been the main consideration in the decision.

METHODS AND PROCEDURES

SEA CUCUMBER POPULATION ASSESSMENT SURVEYS

Objectives

The primary objective of the sea cucumber assessment survey program is to conduct a population assessment survey once every 3 years in each potential fishing area (Figure 1) to estimate the sea cucumber biomass available for commercial harvest. The statistical objective is to estimate the biomass in survey areas such that the lower bound of the one-sided 90% confidence interval is within 30% of the mean value (70% precision). The estimated average weight of sea cucumbers in an area should have a precision level greater than 80%. A second objective is the conduct population assessment surveys every year in several control areas (Figure 2), which are closed to the commercial fishery, to monitor population changes in the absence of harvest.

Sampling Methods

Selection of Commercial Fishery Areas and Survey Areas

Stock assessment surveys of sea cucumber populations in 2010 comprise one of three fishing area rotational groups. Population assessment surveys were conducted in many of the same fishing areas as in 1992, 1995, 1998, 2001, 2004, and 2007. However, if survey results revealed low sea cucumber abundance that precluded a commercial fishery in any year, then that area was generally not surveyed in subsequent years. Conversely, additional new areas have been added over the years and have been surveyed only once or twice in recent years. The selection of fishing areas was decided through negotiation with the sea cucumber industry with an emphasis on providing areas each year near the major communities within the range of commercially viable sea cucumber populations. These communities are Ketchikan, Craig, Wrangell, Petersburg, and Sitka. To provide for stability in the commercial fishery, an attempt was made to place areas in rotations such that guideline harvest levels were roughly equal among rotations. Once an area was included as part of one fishing area rotational group, it remained attached to that rotation and was not subsequently surveyed or fished as part of another rotational group.

Abundance Estimates: The SCUBA Survey Method

Abundance estimates are initiated by SCUBA divers counting all sea cucumbers along 2-meter-wide strip transects running perpendicular to shore. A set of paired transects (two 2-meter-wide transects for each sampling location) serve as the primary sampling unit. Transects extend from the water's edge to 15 m (50 ft) below mean lower low water (MLLW). Transect length varies depending on slope of the bottom. An effort is made to limit exposure to actual depths greater than 18.5 meters because deeper dives severely limit total bottom times for SCUBA divers and pose safety risks when conducted repetitively over several days. The majority of the sea cucumber harvests by commercial divers occur at less than 15 meters depth.

To complete transects, both divers swim along the transect holding a 2-meter rod (a 2.1-cm diameter white PVC tube) in a horizontal position, perpendicular to the census path. Transect direction is maintained by reference to a compass mounted on the rod. Transect pairs are separated by approximately 5 meters or by the limits of visibility of dive partner for safety reasons. Divers slowly progress along each transect searching beneath kelp and between rocks to obtain accurate counts of sea cucumbers. In some areas where there is heavy kelp cover or poor underwater visibility, counts are probably underestimated because some sea cucumbers may be obscured from a diver's view.

At the end of each transect, divers record sea cucumber counts, end depth, predominant vegetative cover and substrate types, the presence of other species of interest (including geoducks, sea urchins and abalone), and any other interesting observations. Presence of vegetation in each segment is recorded as percent cover for up to 2 types. Substrate type is recorded for the 2 most common types on each segment, with the most prevalent type listed first. Definitions of the substrate types and vegetation types recorded during the assessment surveys are included in Appendices A and B. The beginning and ending times for each transect are recorded to allow for later standardization to mean lower low water (MLLW). During the first years of stock assessment surveys, estimates of sea cucumber density and habitat type by depth were recorded (see Larson et al. 2001a; Larson et al 2001b; Hebert et al. 2001a; Hebert et al. 2001b).

The State of Alaska–owned research vessel *R/V Kestrel* was used to support all sea cucumber dive surveys during 2010. In addition to the vessel crew of 3, 6 divers are generally assigned to each cruise, allowing two 3-person dive teams to operate simultaneously. Two aluminum skiffs, which have been enhanced for diving purposes, accompany the support vessel. All diving is conducted from these skiffs.

Due to the nature of the described dive surveys (multiple dives per day, reverse-profile to 70 feet of sea water, multi-day diving), 36% Nitrox was used for all diving conducted in 2010 to reduce the risk of barotrauma injury due to prolonged bottom times. Nitrox is produced onboard via a membrane equipped low-pressure compressor. All diving was conducted in accordance with the Alaska Department of Fish and Game's Dive Safety Manual (Hebert 2006).

Location and Number of Transect Samples

Transect pairs were systematically distributed along the shorelines of each survey area. The location of the first transect pair was randomly chosen, and subsequent transect pairs were located at equal intervals along the shoreline. The distance between transect pairs equals the total length of shoreline divided by the number of transect pairs allocated to each area. The number of transects planned for each area may varied depending on the variety of habitat quality and size of the area. Large areas with more habitat variety may require more transects to achieve the precision goal of the lower bound 90% confidence interval meeting or exceeding 70 percent of the point estimate. Generally the number of transect pairs required to achieve precision goals vary between 15 and 25. Locations of transects completed in 2010 are presented in Appendix C (commercial areas) and Appendix D (control areas).

Transect locations are permanent. If multiple past surveys have resulted in counts of zero on any given transect, that transect may not be sampled and assumed to be zero for purposes of density calculations. Alternatively, if several adjacent transects result in counts of zero, those transects and the corresponding shoreline may be removed from the survey design and considered to be not sea cucumber habitat. Most transect locations are revisited each rotational cycle, allowing paired comparisons of abundance between years without the added variability, due to location effects, that would result from assigning new locations each year. Although this is the current practice, alternative sampling methods may improve evaluation of fluctuations of sea cucumber population levels (Clark et al. 2009). There are no permanent markers at the transect sites to show the survey team where to dive. Transect sites are located using nautical charts showing transect locations supplemented by the use of differential global positioning satellite (DGPS) navigation device. Relocation is generally accurate to within 20 meters depending on the scale of the nautical chart used.

Average Weights

Individual sea cucumbers were collected and weighed in each survey area to estimate average weight of cucumbers. Average sea cucumber weight was estimated in each area for 2 reasons: 1) to compare average weights between years to determine if any significant change in size has occurred; and 2) to convert abundance estimates from number of sea cucumbers to biomass. In 2010, at least 15 sea cucumbers were collected along all odd-numbered transects completed in commercial fishery areas. If samples were unobtainable for more than a few odd-numbered transects (due to low sea cucumber abundance), then samples were collected on even-numbered transects to increase sample area coverage and sample size. In control areas, approximately 40 sea cucumbers were sampled at designated sampling sites that were not at transect locations. Control areas are sampled differently to avoid potentially impacting transect counts from annual collections. Individual sea cucumbers were eviscerated, drained, and then weighed to the nearest gram.

Statistical Analysis

The average number of sea cucumbers per linear meter of shoreline, d, and henceforth called "density" was calculated as:

$$d = \sum_{i=1}^{n} \frac{C_i}{4n} \tag{1}$$

where:

i = transect index,

C_i = the total count of sea cucumbers in a transect pair, and

n = the number of transect pairs.

Division by 4 takes into account the 2 transects of 2 meters width each.

The variance of the mean, σ_d^2, is estimated was:

$$\sigma_d^2 = \frac{\sum_{i=1}^{n}\left(d - \frac{C_i}{4}\right)^2}{(n-1)n} \tag{2}$$

Confidence limits about *d* were calculated using a t-value with *n*-1 degrees of freedom.

Average weight for transect *i*, (W_i) and associated variance of the mean weight (σ_W^2,) for m_i sea cucumbers sampled on transect *i* was estimated as,

$$W_i = \sum_{j=1}^{m_i} \frac{w_{ij}}{m_i}, \tag{3}$$

$$\sigma_W^2 = \frac{\sum_{i=1}^{m}\left(W - w_{ij}\right)^2}{(m-1)m}. \tag{4}$$

The estimated mean weight for the entire subdistrict (W_A) and associated variance of this mean weight are calculated as follows:

$$W_A = \sum_{i=1}^{k} \frac{W_i}{k}, \tag{5}$$

$$\sigma_{W_A}^2 = \frac{\sum_{i=1}^{k}\left(W_i - W_A\right)^2}{(k-1)k}, \tag{6}$$

where *k* equals the number of transects from which a cucumber sample was taken for weight measurements. The average weight and precision of this estimate were used to expand the estimated number of sea cucumbers in an area to the biomass of the population.

Biomass estimates and associated precision were estimated as a product of 2 random variables (Goodman 1960). The total number of sea cucumbers in a subdistrict (N_c) is the product of the average number of sea cucumbers per meter of shoreline and the total estimated length of shoreline (*L*):

$$N_C = Ld, \tag{7}$$

and,

$$\sigma_{N_C}^2 = \sigma_d^2 L^2. \tag{8}$$

The shoreline length estimate is assumed to be measured without error.

The biomass (B_c) is estimated as,

$$B_C = N_C W_A \quad (9)$$

Biomass variance is estimated as,

$$\sigma_{B_C}^2 = (\sigma_d^2 W_A^2 + \sigma_{W_A}^2 d^2 - \sigma_d^2 \sigma_{W_A}^2) L^2 \quad (10)$$

Degrees of freedom associated with the *t*-value for the precision of the biomass estimates are not known, but can be estimated through simulation. The quotas were calculated as the lower 90% confidence limit of the biomass estimate, multiplied by 3 to account for the 3-year rotational openings, and then by 0.064, which is the annual target harvest rate.

RESULTS AND DISCUSSION

COMMERCIAL FISHERY AREAS

Density, Weight, and Biomass

In 2010 the density of sea cucumbers in commercial fishery areas ranged from 15.3, in Subdistrict 101-47, to 1.4 in Subdistricts 110-31,32,33,34 (Table 1; Figure 3). Density of sea cucumbers is variable among fishery areas and among years, and there is no clear trend for most areas (Figures 4–8). Although there may be visual trends of point estimates for some areas, they are often not supported statistically due to overlapping confidence intervals. Areas where there may be some indication of a decline include Subdistrict 101-23, Subdistrict 102-10, Subdistricts 103-11,15, Subdistrict 103-50, and Subdistricts 113-55,56,57,58 (Figure 9). For some of these areas (103-11,15 and 103-50), sea otters are present and are suspected to have contributed to declining sea cucumber populations. Although it is difficult to prove sea otter predation is responsible for sea cucumber declines, observations of large numbers of sea otters have been made in these areas, and other invertebrate species, which are known sea otter prey (e.g. red sea urchins and geoducks), have also declined in these areas. For some areas in the rotation, density appears to be increasing (Subdistricts 101-44,45,46,48, Subdistrict 111-50), or remaining stable (Subdistrict 101-80, Subdistrict 102-50, Subdistricts 106-10,20,22, Subdistricts 113-40,42,43), but for several areas, too few surveys have been completed to see clear trends.

Average sea cucumber weight estimates in 2010 ranged from 134 grams in Subdistricts 101-44,45,46,48, to 289 grams in Subdistricts 113-40,42,43 (Table 2; Figure 10). Average weight appears to be stable over time for most areas, and possibly increasing in some areas (Figures 11–16). There are no areas in the 1992/2010 rotation where there is evidence of declining average weight.

The highest estimate of biomass in 2010 was in Subdistricts 106-10, 20, 22, at 1,215,312 pounds (554,182 kg) and the lowest was in Subdistricts 110-31, 32, 33, 34, at 116,505 pounds (53,126 kg) (Table 3; Figure 17). Biomass estimates are derived from estimates of density and average weight and provide an estimate of overall population levels. Biomass level is directly proportional to the length of shoreline in a given area (Table 4; Figure 18), except in areas where sea otters are present, which results in disproportionately low density. An example of this exception may be found in Subdistricts 103-11, 15, where the shoreline length is the highest among areas in the 1992/2010 rotation; however, biomass estimates are about one-third that of the highest biomass estimate in the rotation, made in Subdistricts 106-10, 20, 22. Although the biomass point estimate for Subdistricts 106-10, 20, 22 was the highest in 2010, and usually is the highest in this rotation, the variation around the point estimate was relatively high, producing a wide confidence interval. Subdistrict 102-40 also produced a high biomass estimate, but with a narrower confidence interval than Subdistricts 106-10, 20, 22. Due to uncertainty (high variance) surrounding the point estimates, it is possible that a higher biomass was present in Subdistrict 102-40 or Subdistrict 101-23 in 2010 than estimated for Subdistricts 106-10, 20, 22.

Although tracking estimates of sea cucumber biomass over time may be an acceptable way to observe trends in overall population levels, it must be done with caution. The reason for this is that biomass estimates are calculated using the length of shoreline (see Table 4) for each area, which may fluctuate for a variety of reasons. Reasons may include adding to or combining of fishery areas, opening or closing areas to the commercial fishery by the Board of Fisheries, refining shoreline measurements, or improving delineation of sea cucumber habitat. The addition or removal of sections of shoreline from survey areas results in changes in biomass estimates that are not a result of changes in population levels. For this reason, shoreline changes must be considered when evaluating trends in biomass.

Trends in biomass follow closely to trends in sea cucumber density. Areas where there may be some indication of a decline in biomass include Subdistrict 101-23, Subdistrict 102-10, Subdistricts 103-11, 15, Subdistrict 103-50, and Subdistricts 113-55, 56, 57, 58. Sea otter predation is suspected for the declines apparent in District 3, and Subdistrict 102-10. For some areas in the rotation, biomass appears to be increasing (Subdistricts 101-44, 45, 46, 48, Subdistrict 111-50), or remaining stable (Subdistrict 101-80, Subdistrict 102-50, Subdistricts 106-10, 20, 22, Subdistricts 113-40, 42, 43), but for several areas, too few surveys have been completed to see trends (Figures 19-24). As expected, these trends are consistent with those observed for sea cucumber density.

Guideline Harvest Levels

Harvest levels are currently calculated using a harvest rate of 19.2% (this is a 3-year pooled annual harvest rate of 6.4%), applied to the lower bound of the 90% confidence interval surrounding the biomass estimate. Potential GHLs, based on this calculation are presented in Table 5. The actual GHLs that have been used for fishery management are shown in Table 6. These values may differ slightly in recent years due to rounding up or down for ease of reporting in news releases. Actual GHLs from earlier years differed from potential GHLs because the survey was relatively new and results were used to help guide setting appropriate harvest levels, rather than determine GHLs. In many cases, but not all, GHLs during early years were set higher than those calculated using the current harvest rate.

The area in the 1992/2010 rotation with the highest GHL is Subdistrict 102-40 (Cholmondeley Sound on east Prince of Wales Island) and the second highest GHL is in Subdistrict 101-23 (Figure 25). These 2 areas comprised 22% of the total regional GHL established for the 2010/2011 fishing season. Subdistricts 106-10, 20, 22 (Upper Clarence Strait/McHenry Inlet area) and Subdistricts 112-12, 13, 50 (Upper Chatham Strait/Freshwater Bay) also contributed substantially to the regional GHL. These top 4 areas combined comprised 40% of the 2010/2011 regional GHL.

Observation of trends in GHLs over time is fundamentally different than observing trends in biomass or population level. This is because biomass estimates are considered with estimates of error, whereas GHLs are not. If estimates of error (e.g. confidence intervals) overlap, it may not be possible to conclude that the biomass in an area has undergone a statistically significant declined or increased. However, it is noticeable when there are fluctuations or trends in GHLs. Because GHLs are calculated in proportion to biomass (and precision), which is derived from shoreline, the same cautions apply to considering fluctuations in GHLs as for biomass. That is, if shoreline values used to calculate biomass and GHL have changed, they must be considered when viewing fluctuations in GHL.

When 2010/2011 GHLs are compared to those established for the 2007/2008 commercial fishery, of areas where a fishery occurred in 2007/2008, the GHL declined in more than half of the areas (12 of 19 areas) (see Figures 26–31). The GHL has increased in four areas over the same time period, and remained the same or close to the same in three areas.

CONTROL AREAS

Control areas are survey sites in subdistricts or portions of subdistricts that have been closed to commercial harvest by the Board of Fisheries and are surveyed using very similar techniques as those used to survey commercial fishery areas. The intent is to monitor these areas to evaluate fluctuations of sea cucumber density, weight, in the absence of commercial harvest. Population trends in these areas help determine the extent that fluctuations in the environmental contribute to fluctuations of populations.

Five control areas have been consistently surveyed annually since 2000, and 3 of these since 1998 (see Figure 2). Trends in sea cucumber density among control areas are mixed, with some areas apparently in decline through 2009 (e.g. Subdistrict 101-27 south of Ketchikan and Subdistrict 113-41 control near Sitka), and some apparently stable (Table 7; Figure 32). However, results from 2010 surveys suggest that density increased dramatically in 4 of 5 areas (a Subdistrict 113-40 control area may have increased, but not substantially). The substantial density increase in most of the control areas suggests a regional environmental effect. The increase could be explained by a large recruitment event. Average weight in all control areas apparently declined between 2009 and 2010 (Table 8; Figure 33), which would be expected if there was a substantial recruitment of young sea cucumbers. There are 3 control areas where sea otters are known to be in the general area (Subdistricts 103-40 control, 103-60 control, 113-41 control). Of these areas, only Subdistrict 113-41 control appears to have decreased over time. It is unclear why sea cucumber populations in other control areas where sea otters reside have not been severely affected. The apparent decline in sea cucumber density in some control areas suggests that if there are declines in commercial fishery areas, they are not necessarily due exclusively to fishery mortality.

Biomass estimates in control areas follow very similar patterns over time as density estimates (Table 9; Figure 34). This is because biomass estimates are calculated directly from density and average weight estimates, and average weight has remained stable over time. Overall variance of biomass estimates (expressed as confidence intervals in Figure 34) has remained at a relatively low level in control areas, suggesting that estimates are relatively precise. The statistical objective of maintaining the percent precision at least within 70% of the point estimate of biomass has been achieved or exceeded in most areas for most years. This result increases confidence that trends observed in populations are real, as opposed to being uncertain due to estimate error.

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TABLES AND FIGURES

Table 1.–Average sea cucumbers per meter of shoreline ("density") from surveys in commercial fishery subdistricts of Southeast Alaska.

Survey year	101-11-002	101-21	101-23	101-44,45, 46,48	101-47	101-51,55	101-60, 71,73	101-80	102-10	102-40	102-50	103-11,15	103-50
1992			28.2					5.1	11.6		10.9		8.6
1995			22.5					3.9	10.9		13.6		8.6
1998			21.7	7.1				4.7	8.7		13.7		7.4
2001			19.9	11.7				4.6	5.8	17.4	11.4	8.4	8.9
2004	10.9		16.2	9.4				4.4	5.5	17.1	15.6	7.5	5.0
2007	10.9		13.9	9.4		8.2	5.8	2.8	11.7	17.7	11.9	4.3	3.7
2010	7.4	10.2	15.0	12.0	15.3	5.9	4.3	4.1	5.0	12.4	13.6	2.0	3.2

Survey year	105-41,42	106-10, 20,22	109-20	109-41,42	109-62	110-31,32, 33,34	111-50	112-12,13,50	112-18,19, 80,90	112-15,61, 114-25	113-40, 42,43	113-55,56, 57,58	183-10[a]
1992					12.4				10.4		12.9	11.2	
1995	9.0	17.4			6.0				7.2		10.0	10.1	
1998	5.7	21.3			11.0				5.1		15.3	8.1	
2001	3.4	20.5			7.3			17.1	6.6		9.8	7.9	
2004		20.3			0.1		2.5	12.2	5.1	6.0	12.3	4.6	
2007		12.9	6.3	3.4			2.7	10.1	7.6	5.6	11.0	6.2	6.9
2010		13.4	6.8	3.2		1.4	3.9	12.6	6.6	7.0	7.2	4.3	5.4

[a] 2007 estimate was actually made in 2005.

Table 2.–Average sea cucumber weight (grams) from surveys in commercial fishery subdistricts of Southeast Alaska.

Survey year	101-11-002	101-21	101-23	101-44,45, 46,48	101-47	101-51,55	101-60, 71,73	101-80	102-10	102-40	102-50	103-11,15	103-50
1992			217					184	305		197		239
1995			221					204	218		190		225
1998			212	136				164	206		164		203
2001			214	156				156	251	221	156	236	209
2004	206		214	158				190	244	221	196	220	212
2007	205		227	150		146	160	191	217	216	208	307	256
2010	197	191	206	134	238	146	152	184	252	214	193	240	205

Survey year	105-41,42	106-10, 20,22	109-20	109-41,42	109-62	110-31,32, 33,34	111-50	112-12,13,50	112-18,19, 80,90	112-15,61, 114-25	113-40, 42,43	113-55,56, 57,58	183-10[a]
1992					169				242		243	195	
1995	300	218			165				219		259	172	
1998	211	228			174				239		227	193	
2001	179	227			153			181	220		218	192	
2004		244			153		216	194	263	234	229	213	
2007		245	242	277			192	208	249	229	251	251	215
2010		240	212	287		238	189	192	244	215	289	224	206

[a] 2007 estimate was actually made in 2005.

Table 3.–Total sea cucumber biomass in pounds for Southeast Alaska fishery subdistricts.

Survey year	101-11-002	101-21	101-23	101-44,45,46,48	101-47	101-51,55	101-60,71,73	101-80	102-10	102-40	102-50	103-11,15	103-50
1992			1,877,000					457,000	1,365,000		495,000		771,000
1995			1,526,000					384,000	918,000		595,000		726,000
1998			1,416,000	452,000				371,000	694,000		515,000		570,000
2001			1,312,000	849,683				344,552	564,130	1,408,773	411,051	1,144,657	700,646
2004	547,478		1,065,715	693,216				406,234	515,776	1,385,671	699,892	941,124	397,999
2007	547,052		967,404	657,914		453,193	301,261	259,042	394,299	1,409,434	568,971	759,420	352,881
2010	357,143	341,929	952,001	585,818	309,783	321,937	233,572	366,406	488,985	973,595	603,551	280,151	249,054

Survey year	105-41,42	106-10,20,22	109-20	109-41,42	109-62	110-31,32,33,34	111-50	112-12,13,50	112-18,19,80,90	112-15,61,114-25	113-40,42,43	113-55,56,57,58	183-10[a]
1992					1,025,000				363,000		1,118,000	738,000	
1995	775,000	1,439,000			485,000				227,000		839,000	534,000	
1998	347,000	1,845,000			933,000				175,000		1,123,000	526,000	
2001	177,000	1,761,544			544,000			893,286	210,078		683,784	513,452	
2004		1,881,300			3,732		181,345	685,016	194,850	178,328	899,994	328,091	
2007		1,202,983	396,624	321,259			174,958	606,840	272,239	161,554	882,393	413,746	232,543
2010		1,215,312	374,295	313,041		116,505	249,485	702,739	233,159	191,401	668,427	324,491	172,379

[a] 2007 estimate was actually made in 2005.

Table 4.– Linear shoreline measurement in meters of cucumber habitat used to estimate biomass in Southeast Alaska fishery subdistricts.

Survey year	101-11-002	101-21	101-23	101-44,45,46,48	101-47	101-51,55	101-60,71,73	101-80	102-10	102-40	102-50	103-11,15	103-50
1992			139,641					220,388	175,940		104,453		171,310
1995			139,641					220,388	175,940		104,453		171,310
1998			139,641	211,869				220,388	175,940		104,453		171,310
2001			139,641	211,869				220,388	175,940	166,740	104,453	260,738	171,310
2004	111,306		139,641	211,869				220,388	175,940	166,740	104,453	260,738	171,310
2007	111,306		139,641	211,869		171,325	146,678	220,388	70,376	166,740	104,453	260,738	171,310
2010	111,306	80,023	139,641	211,869	38,480	171,325	164,241	220,388	175,940	166,740	104,454	260,738	171,310

Survey year	105-41,42	106-10,20,22	109-20	109-41,42	109-62	110-31,32,33,34	111-50	112-12,13,50	112-18,19,80,90	112-15,61,114-25	113-40,42,43	113-55,56,57,58	183-10[a]
1992					221,684				65,376		161,309	153,160	
1995	130,822	172,144			221,684				65,376		146,493	153,160	
1998	130,822	172,144			221,684				65,376		146,493	153,160	
2001	130,822	172,144			221,684			131,426	65,376		144,995	153,160	
2004		172,144			221,684		154,249	131,426	65,376	57,334	144,995	153,160	
2007		172,144	118,557	156,788			154,249	131,426	65,376	57,334	144,995	153,160	71,110
2010		172,144	118,557	156,788		154,249	154,249	131,426	65,376	57,334	144,995	153,160	71,110

[a] 2007 estimate was actually made in 2005.

Table 5.–Potential commercial harvest levels in pounds based on 6.2% annual harvest rate for fishery subdistricts in Southeast Alaska. The abbreviation “nf” signifies no fishery in that area and year.

Survey year	101-11-002	101-21	101-23	101-44,45,46,48	101-47	101-51,55	101-60,71,73	101-80	102-10	102-40	102-50	103-11,15	103-50
1992			214,788					60,464	145,028		50,537		107,750
1995			183,057					45,812	118,903		63,835		92,868
1998			176,599	61,098				51,973	70,999		67,809		58,486
2001			162,203	125,062				43,717	67,702	206,665	48,360	130,419	77,712
2004	47,858		136,824	99,798				57,462	56,574	188,655	89,621	97,671	43,346
2007	50,874		132,265	100,539		66,379	36,562	36,040	32,967	202,445	68,312	79,393	40,012
2010	49,363	34,742	132,051	80,414	44,083	40,200	32,600	50,200	31,900	149,500	70,100	23,300	24,000

Survey year	105-41,42	106-10,20,22	109-20	109-41,42	109-62	110-31,32,33,34	111-50	112-12,13,50	112-18,19,80,90	112-15,61,114-25	113-40,42,43	113-55,56,57,58	183-10[a]
1992					113,825				40,246		155,809	109,479	
1995	76,580	165,275			56,900				17,429		124,543	70,368	
1998	33,704	202,956			104,103				24,716		99,908	70,887	
2001	17,200	252,887			47,277			126,693	26,408		92,548	62,294	
2004		270,319			nf		19,180	95,246	23,586	17,163	99,418	38,371	
2007		167,009	50,966	32,377			18,273	87,150	24,461	19,399	92,699	53,938	32,313
2010		119,500	47,600	31,900		nf	28,000	104,300	28,900	17,500	79,200	43,500	20,970

[a] 2007 value was actually made in 2005.

Table 6.–Actual commercial fishery guideline harvest levels (GHLs) in pounds for fishery subdistricts in Southeast Alaska. The abbreviation "nf" signifies no fishery in that area and year.

Survey year	101-11-002	101-21	101-23	101-44,45, 46,48	101-47	101-51,55	101-60, 71,73	101-80	102-10	102-40	102-50	103-11,15	103-50
1992			234,313					69,308	104,029		79,755		93,288
1995			213,000					53,700	130,200		77,600		109,000
1998			176,559	61,000				51,973	70,999		69,465		58,486
2001			162,200	125,100				nf	67,700	206,700	48,400	130,400	77,700
2004	47,900		136,800	99,800				57,500	56,600	188,700	89,600	97,700	43,300
2007	50,900		132,300	100,500		66,400	36,600	36,000	33,000	202,500	68,300	79,400	40,000
2010	49,400	34,700	132,000	80,400	44,100	40,200	32,600	50,200	31,900	149,500	70,100	23,300	24,000

Survey year	105-41,42	106-10, 20,22	109-20	109-41,42	109-62	110-31,32, 33,34	111-50	112-12,13,50	112-18,19, 80,90	112-15,61, 114-25	113-40, 42,43	113-55,56, 57,58	183-10[a]
1992					191,773				42,090		155,131	107,289	
1995	89,500	178,300			65,700				25,000		134,600	80,900	
1998	33,704	202,956			104,103				25,848		99,908	71,304	
2001	nf	251,800			47,300			126,700	26,400		92,500	62,300	
2004		270,300			nf		19,200	95,200	23,600	17,200	99,400	38,400	
2007		167,000	51,000	32,400			18,300	87,200	24,500	19,400	92,700	53,900	31,200
2010		119,500	47,600	31,900		nf	28,000	104,300	28,900	17,500	79,200	43,500	nf

[a] 2007 value was actually established in 2005.

Table 7.–Average sea cucumbers per meter of shoreline ("density") from surveys in control area subdistricts of Southeast Alaska.

Survey year	101-27 con	103-40 con	103-60 con	106-30 con	113-40 con
1998	20.0		14.4	29.3	
1999	15.2		13.3	31.7	
2000	16.8	10.1	17.3	23.5	7.8
2001	16.3	11.6	14.1	21.9	5.6
2002	10.3	4.4	7.1	16.9	6.0
2003	18.6	12.2	18.6	18.8	5.9
2004	10.9	7.8	14.9	26.2	5.4
2005	14.3	9.3	13.3	24.2	5.1
2006	12.4	11.0	13.9	26.7	4.2
2007		8.9	11.8	48.1	3.7
2008	7.4	7.9	10.6		
2009	8.8	8.3	12.1	14.2	3.9
2010	22.0	19.7	22.1	44.5	4.2

Table 8.–Average sea cucumber weight (grams) from surveys in control area subdistricts of Southeast Alaska.

Survey year	101-27 con	103-40 con	103-60 con	106-30 con	113-40 con
1998	257		223	261	
1999	228		220	259	
2000	239	274	209	262	232
2001	232	327	254	292	238
2002		238	225	313	223
2003	252	228	238	306	208
2004	255	203	214	325	216
2005	250	266	230	312	212
2006	262	239	229	296	215
2007		288	224	303	216
2008	214	258	227		
2009	238	316	246	336	257
2010	222	274	228	319	225

Table 9.–Total sea cucumber biomass in pounds for control area subdistricts in Southeast Alaska.

Survey year	101-27 con	103-40 con	103-60 con	106-30 con	113-40 con
1998	612,270		137,474	530,015	
1999	413,499		125,361	568,353	
2000	477,039	116,442	155,340	425,977	92,398
2001	451,499	159,574	153,273	444,202	68,155
2002		44,510	68,943	365,979	68,023
2003	559,192	117,606	189,921	400,348	62,403
2004	331,954	66,205	137,145	590,642	59,557
2005	425,248	104,025	131,672	523,007	55,041
2006	388,922	111,011	136,595	548,668	45,943
2007		107,616	113,221	1,013,444	40,397
2008	188,146	86,083	103,390		
2009	248,582	110,654	127,312	331,118	50,701
2010	582,387	227,365	215,637	987,538	48,227

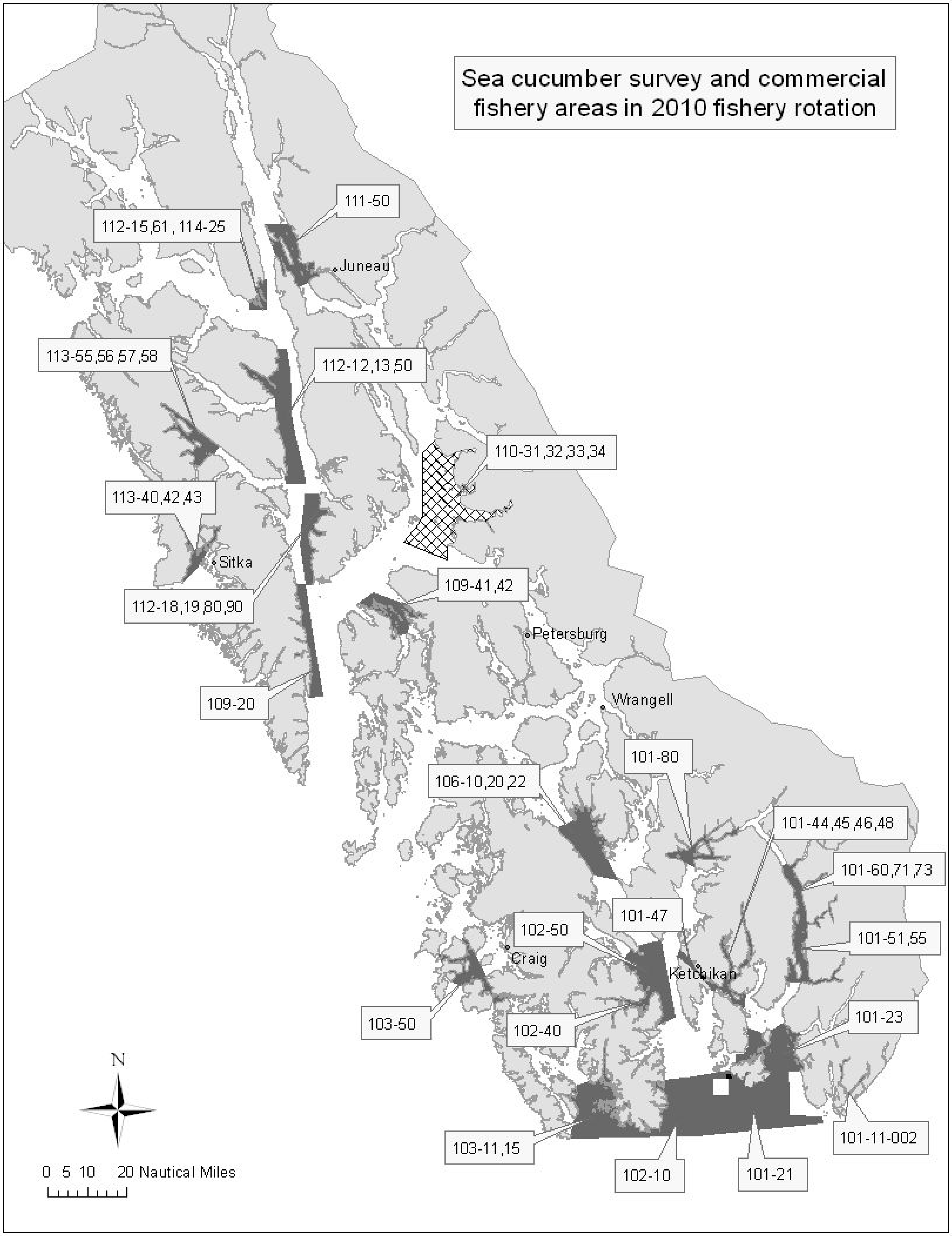


Figure 1.–Location of Southeast Alaska sea cucumber commercial fishery subdistricts in 1992/2010 fishery rotation. Areas shaded gray represent areas surveyed in 2010 and opened in 2010/2011 commercial fishery. Cross-hatched areas were surveyed but not opened for the 2010/2011 season.

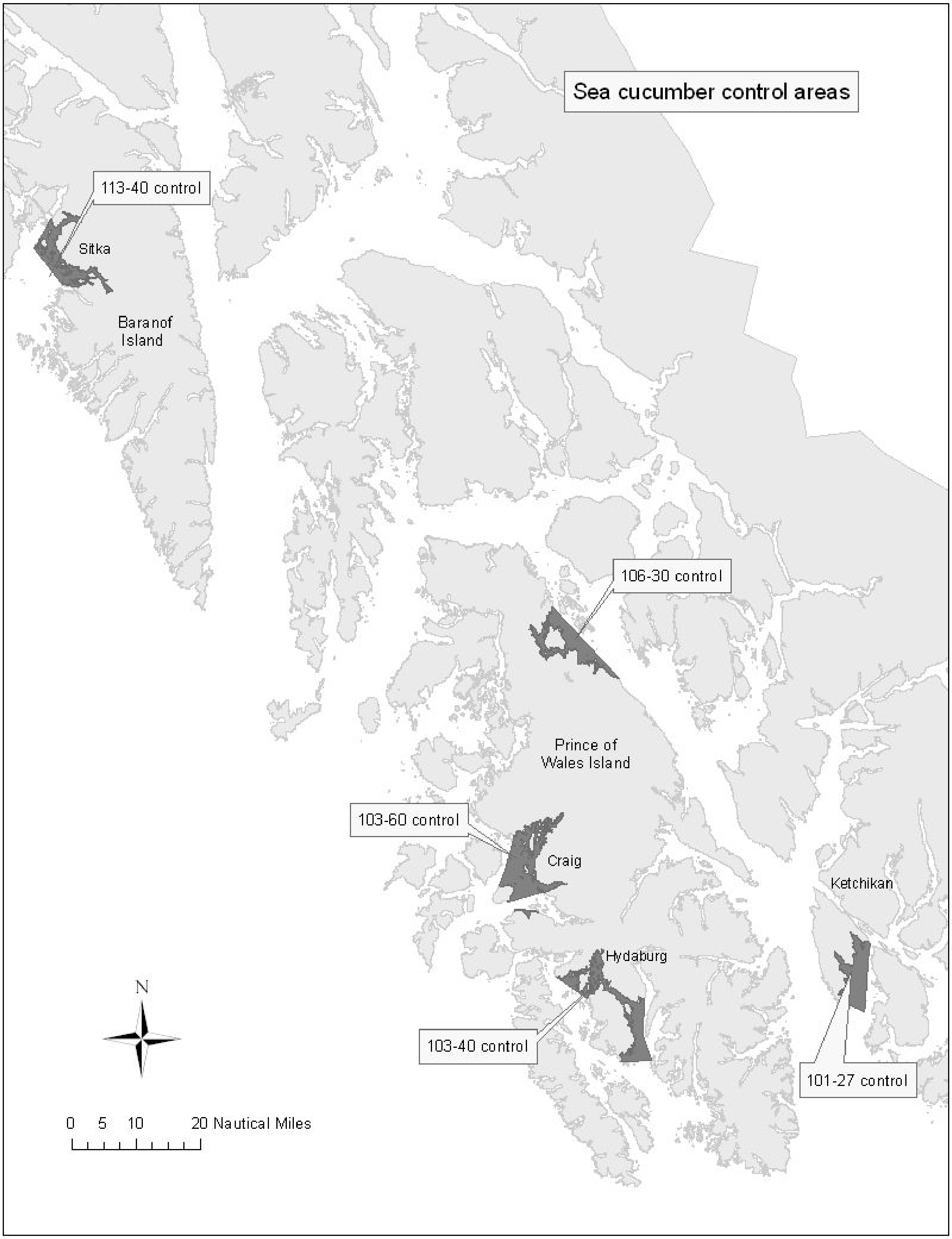


Figure 2.–Location of sea cucumber control (closed to commercial harvest) areas in Southeast Alaska.

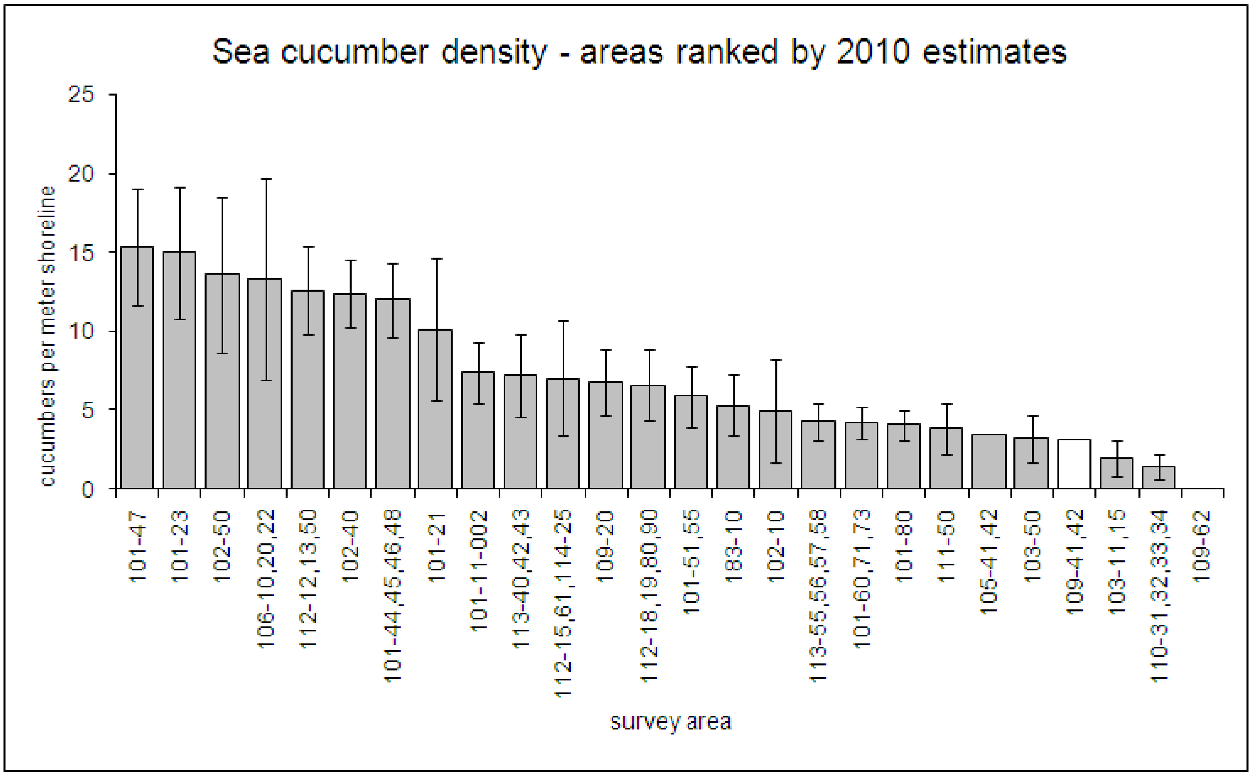


Figure 3.–Estimated sea cucumbers per meter of shoreline in Southeast Alaska, ranked by survey area using 2010 estimates. Bars without shading represent values from surveys prior to 2010 as no survey was conducted in 2010, and are shown for comparison. Error bars represent 90% confidence intervals.

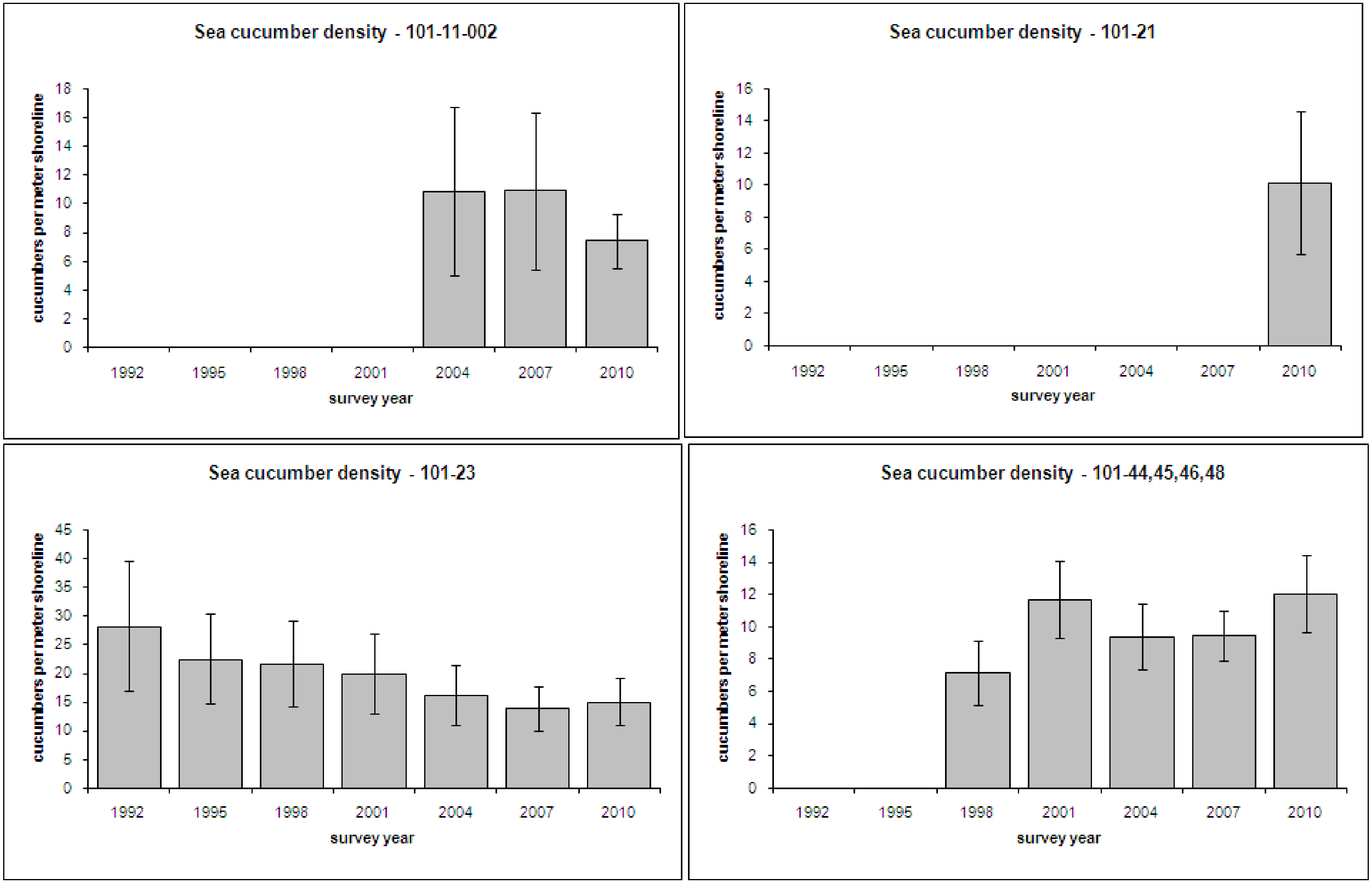


Figure 4.–Average number of sea cucumbers per meter of shoreline from surveys in commercial fishery Subdistrict 101-11-002, Subdistrict 101-21, Subdistrict 101-23, and Subdistricts 101-44,45,46,48 in Southeast Alaska. Error bars represent 90% confidence intervals.

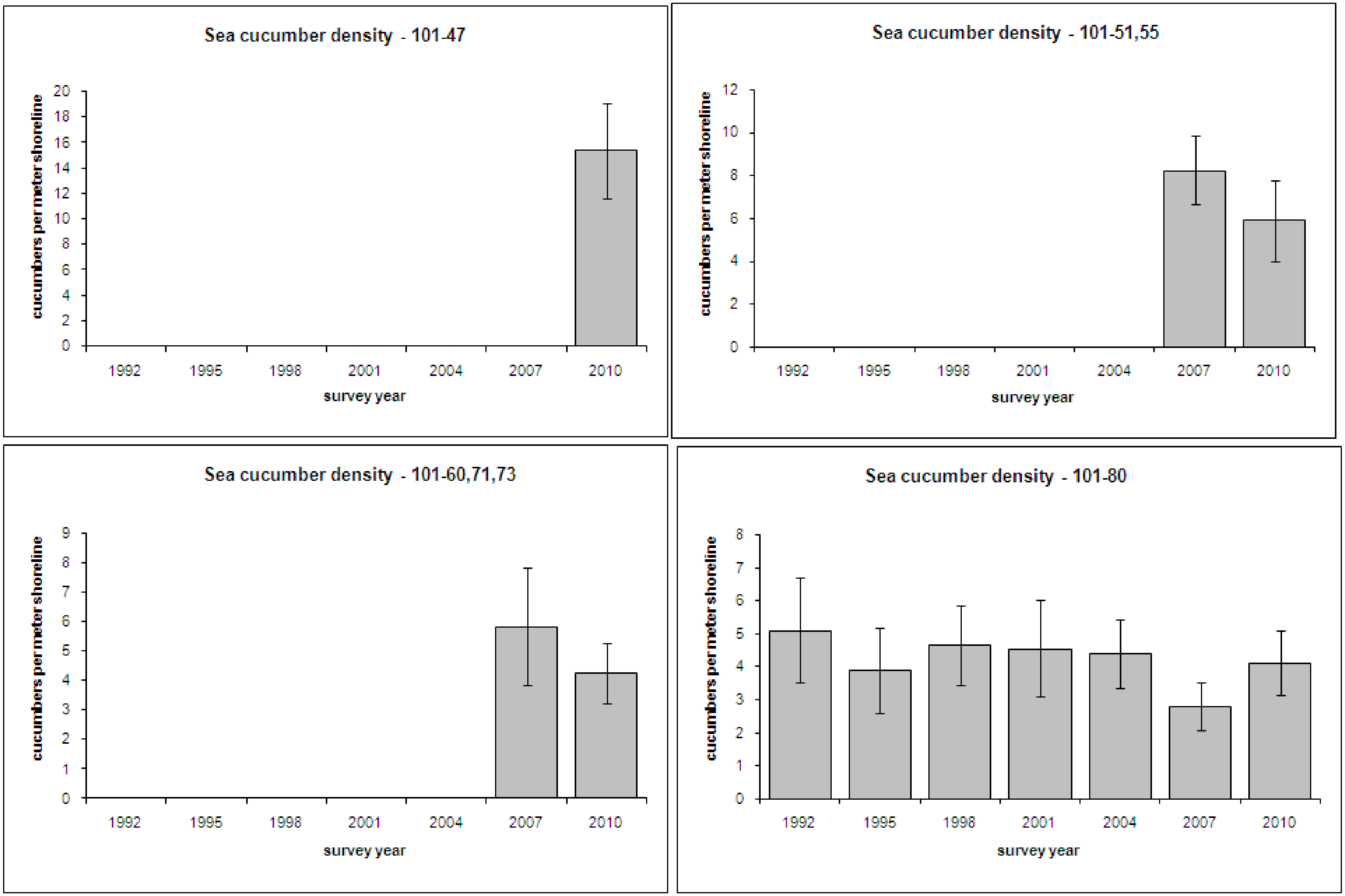


Figure 5.–Average number of sea cucumbers per meter of shoreline from surveys in commercial fishery Subdistrict 101-47, Subdistricts 101-51,55, Subdistricts 101-60,71,73, and Subdistrict 101-80 in Southeast Alaska. Error bars represent 90% confidence intervals.

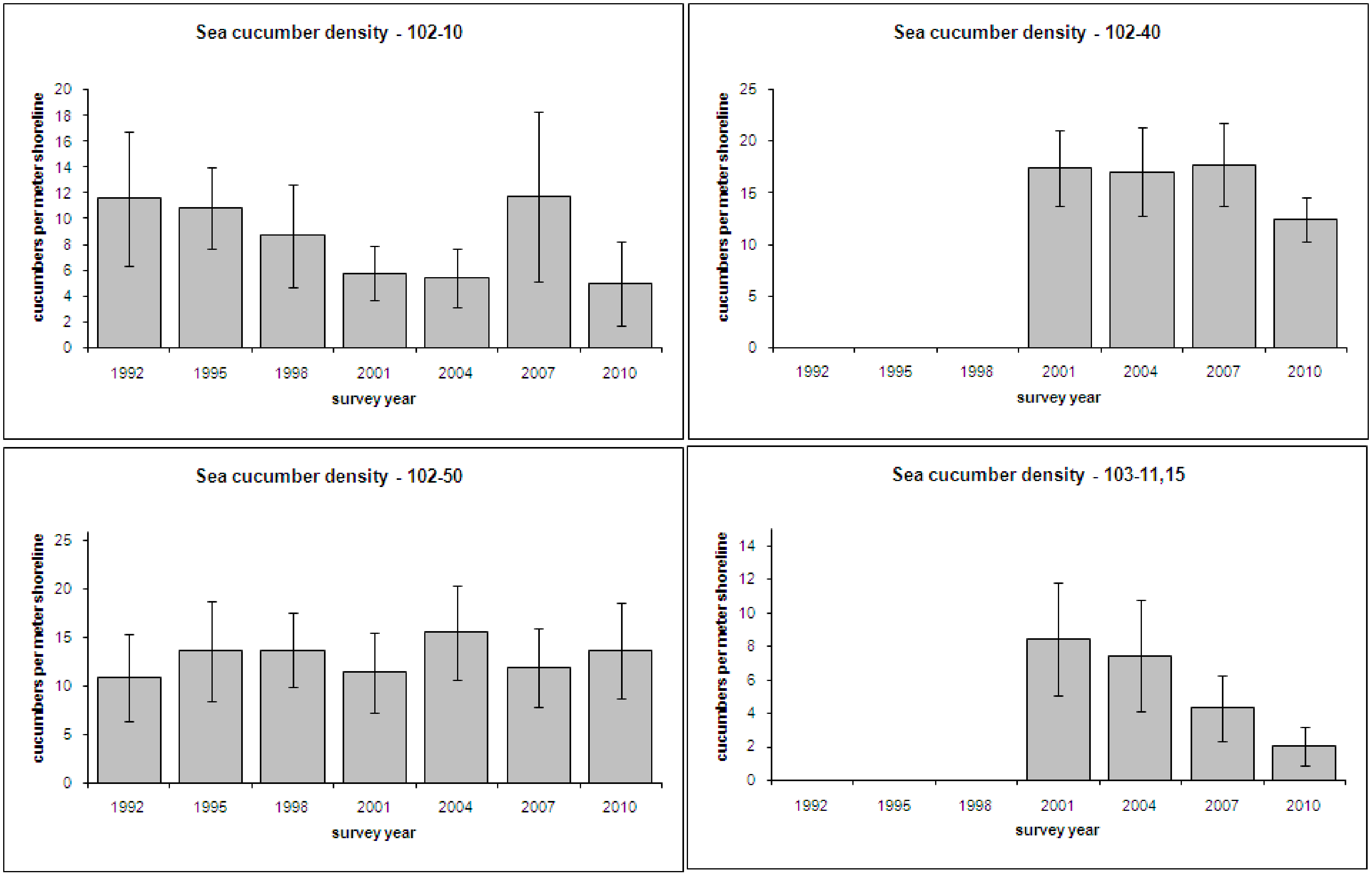


Figure 6.–Average number of sea cucumbers per meter of shoreline from surveys in commercial fishery Subdistrict 102-10, Subdistrict 102-40, Subdistrict 102-50, and Subdistricts 103-11,15 in Southeast Alaska. Error bars represent 90% confidence intervals.

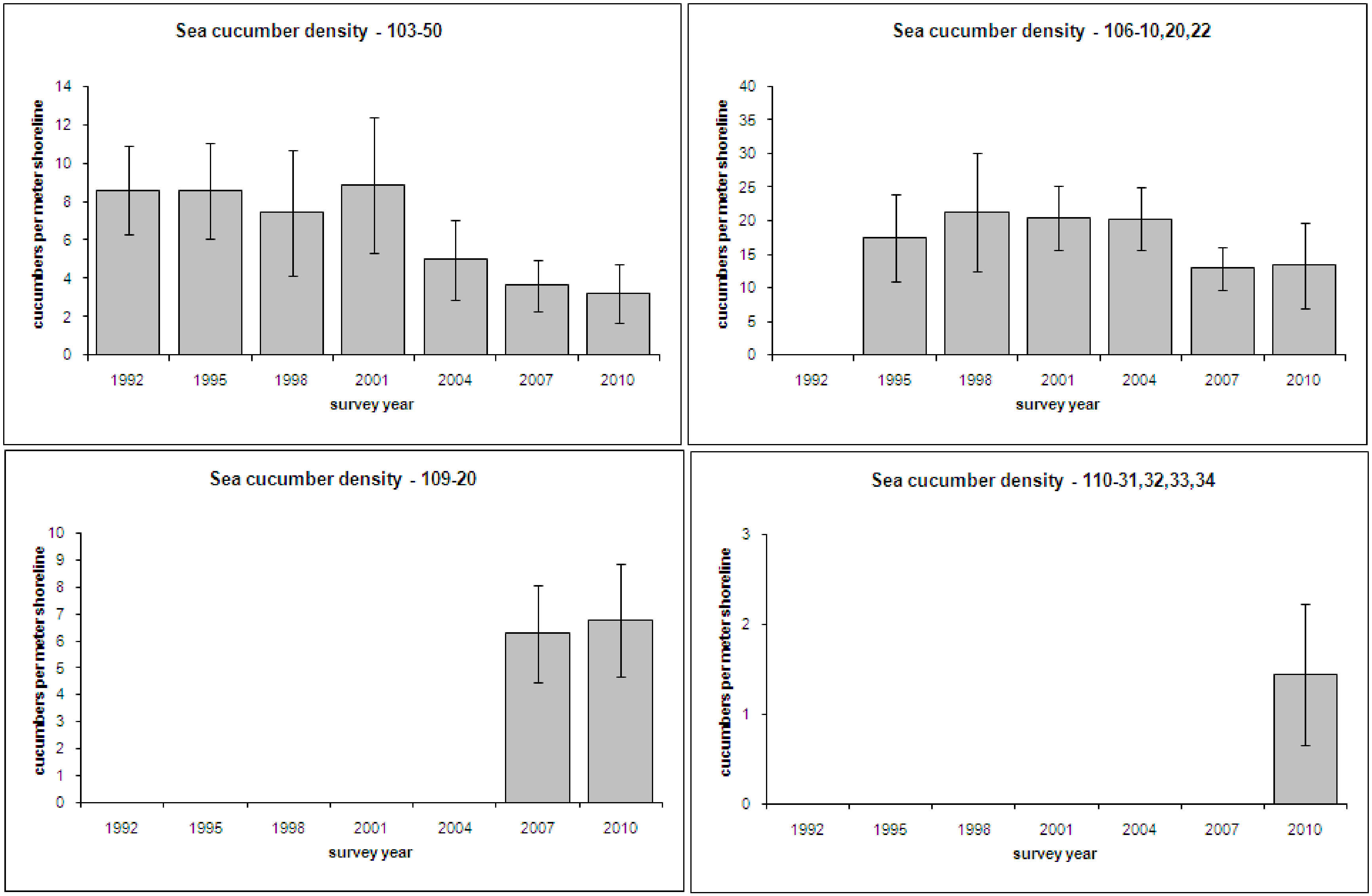


Figure 7.–Average number of sea cucumbers per meter of shoreline from surveys in commercial fishery Subdistrict 103-50, Subdistrict 106-10,20,22, Subdistrict 109-20, and Subdistricts 110-31,32,33,34 in Southeast Alaska. Error bars represent 90% confidence intervals.

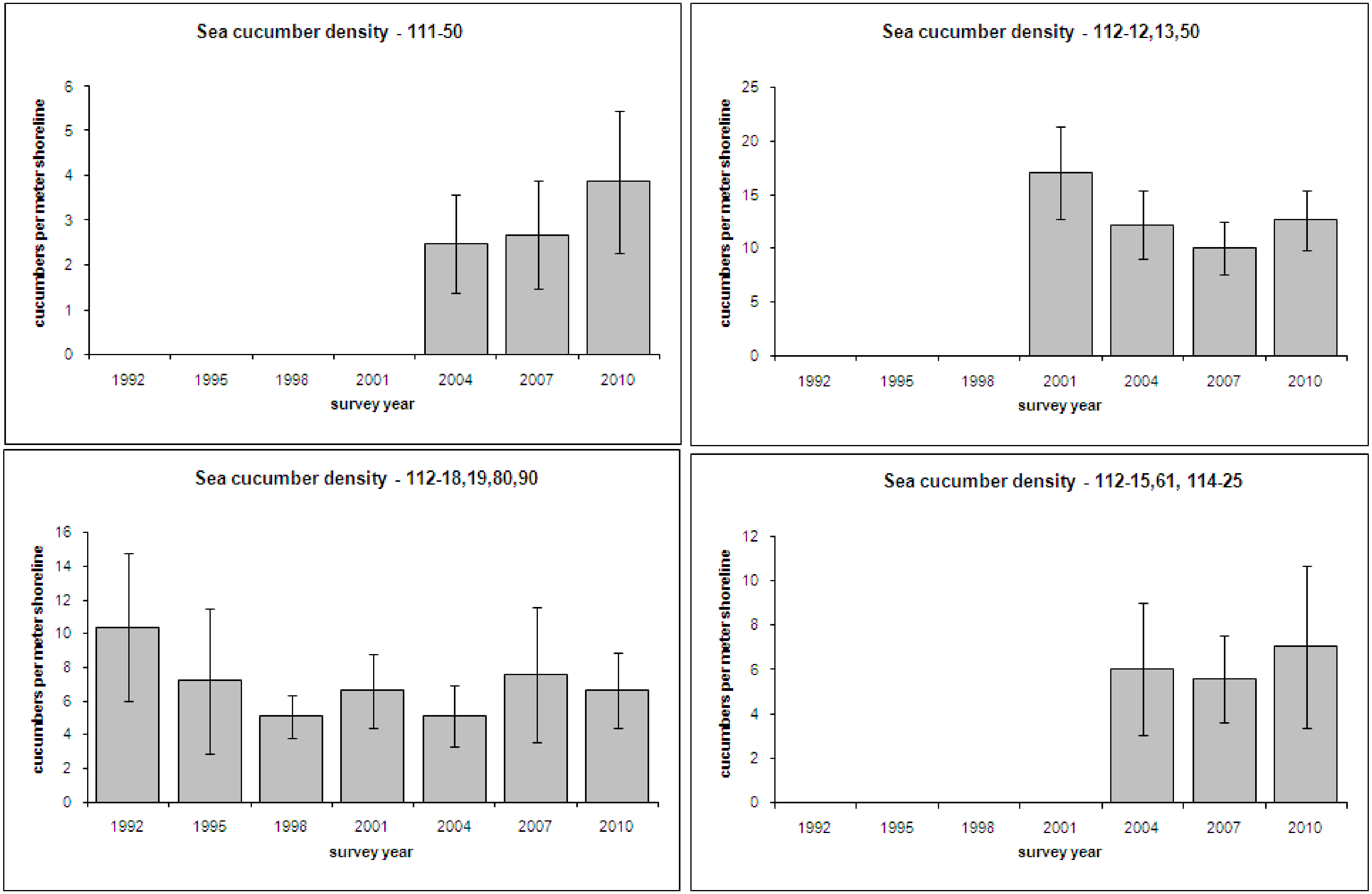


Figure 8.–Average number of sea cucumbers per meter of shoreline from surveys in commercial fishery Subdistrict 111-50, Subdistricts 112-12,13,50, Subdistricts 112-18,19,80,90, and Subdistricts 112-15,61,114-25, in Southeast Alaska. Error bars represent 90% confidence intervals.

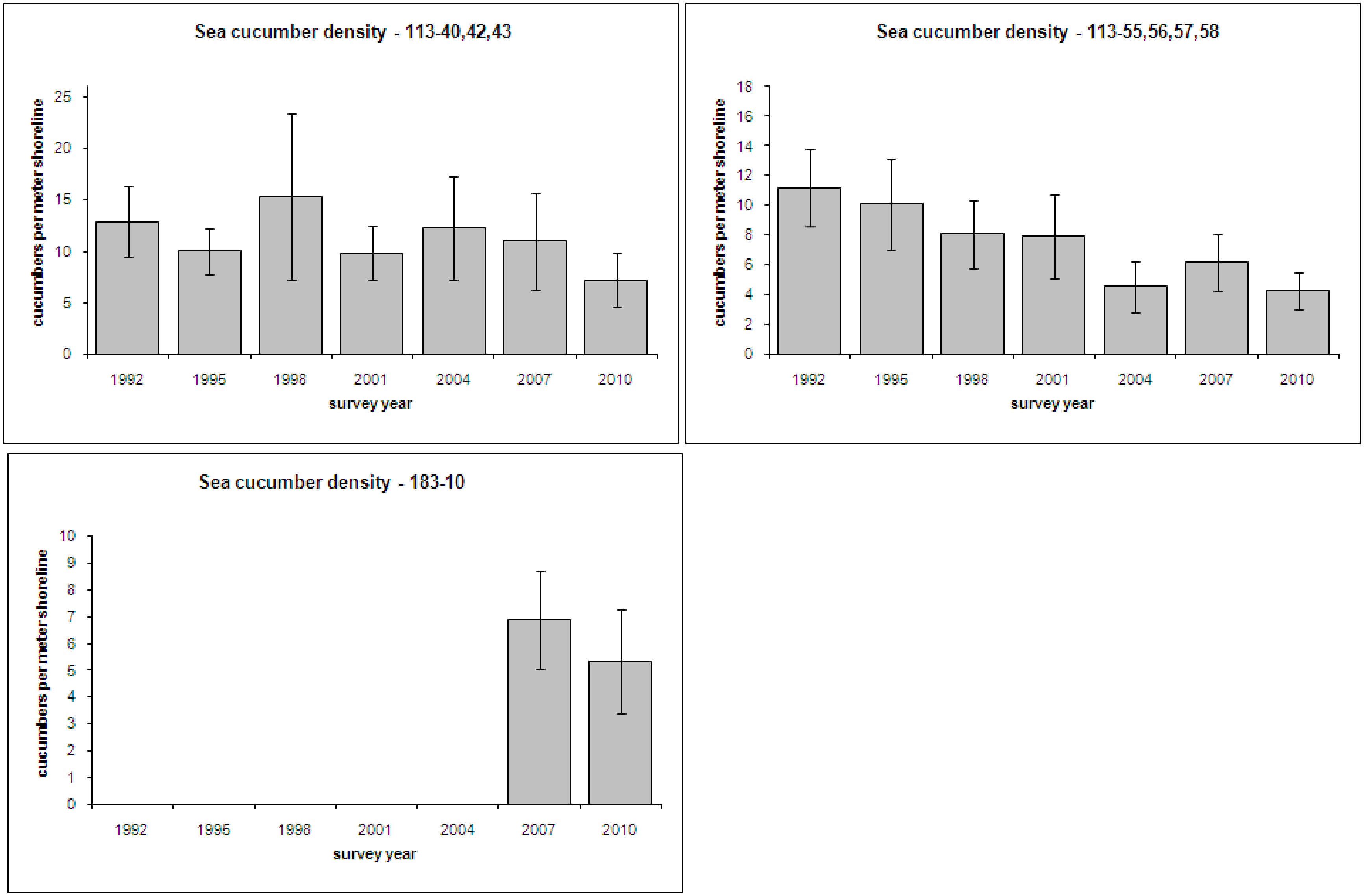


Figure 9.–Average number of sea cucumbers per meter of shoreline from surveys in commercial fishery Subdistricts 113-40,42,43, Subdistricts 113-55,56,57,58, Subdistricts 112-18,19,80,90, and Subdistrict 183-10, in Southeast Alaska. Error bars represent 90% confidence intervals.

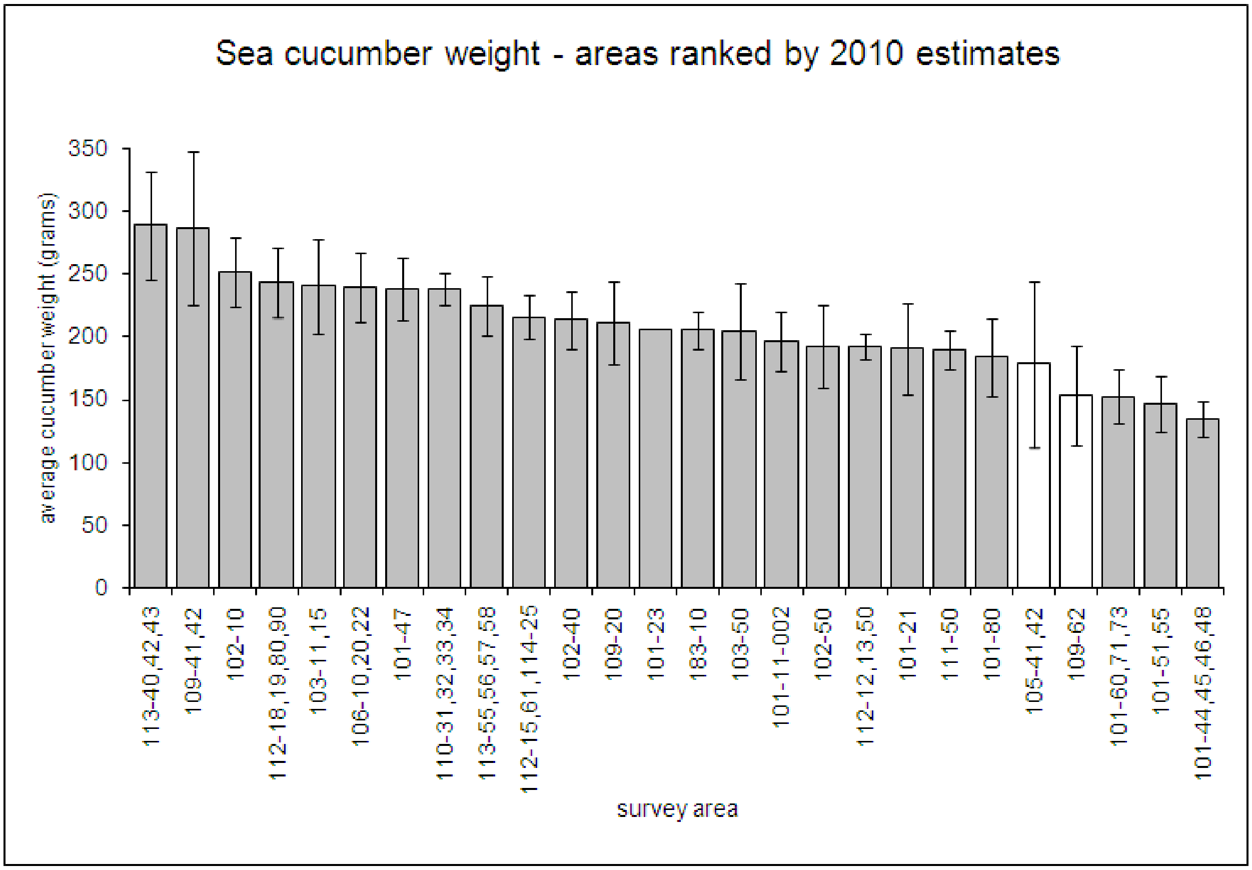


Figure 10.–Estimated sea cucumbers average weight in Southeast Alaska, ranked by survey area using 2010 estimates. Bars with no shading represent values from surveys prior to 2010 as no survey was conducted in 2010 and are shown for comparison. Error bars represent 90% confidence intervals.

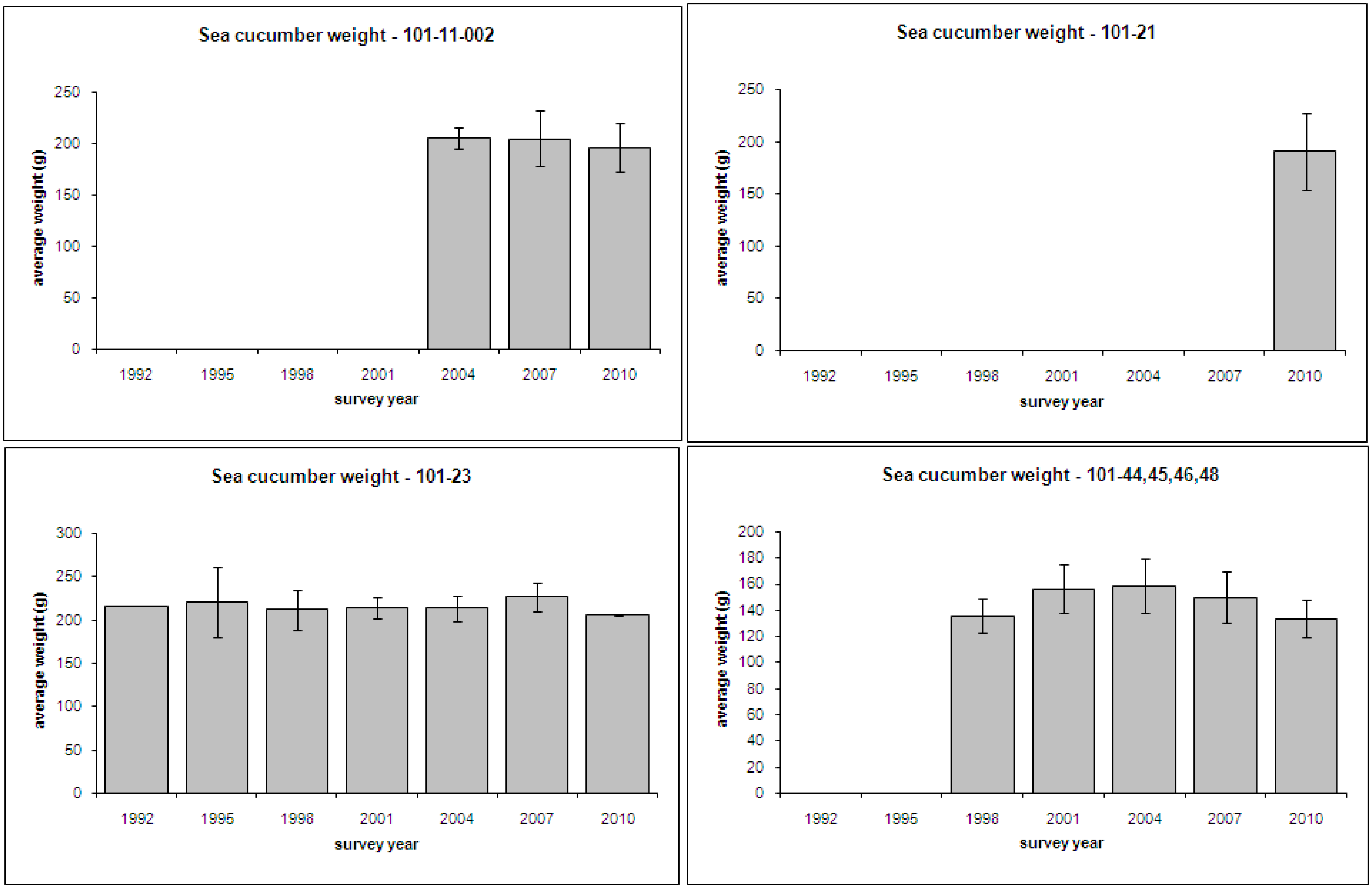


Figure 11.–Average sea cucumber weight (grams) from surveys in commercial fishery Subdistrict 101-11-002, Subdistrict 101-21, Subdistrict 101-23, and Subdistricts 101-44,45,46,48 in Southeast Alaska. Error bars represent 90% confidence intervals.

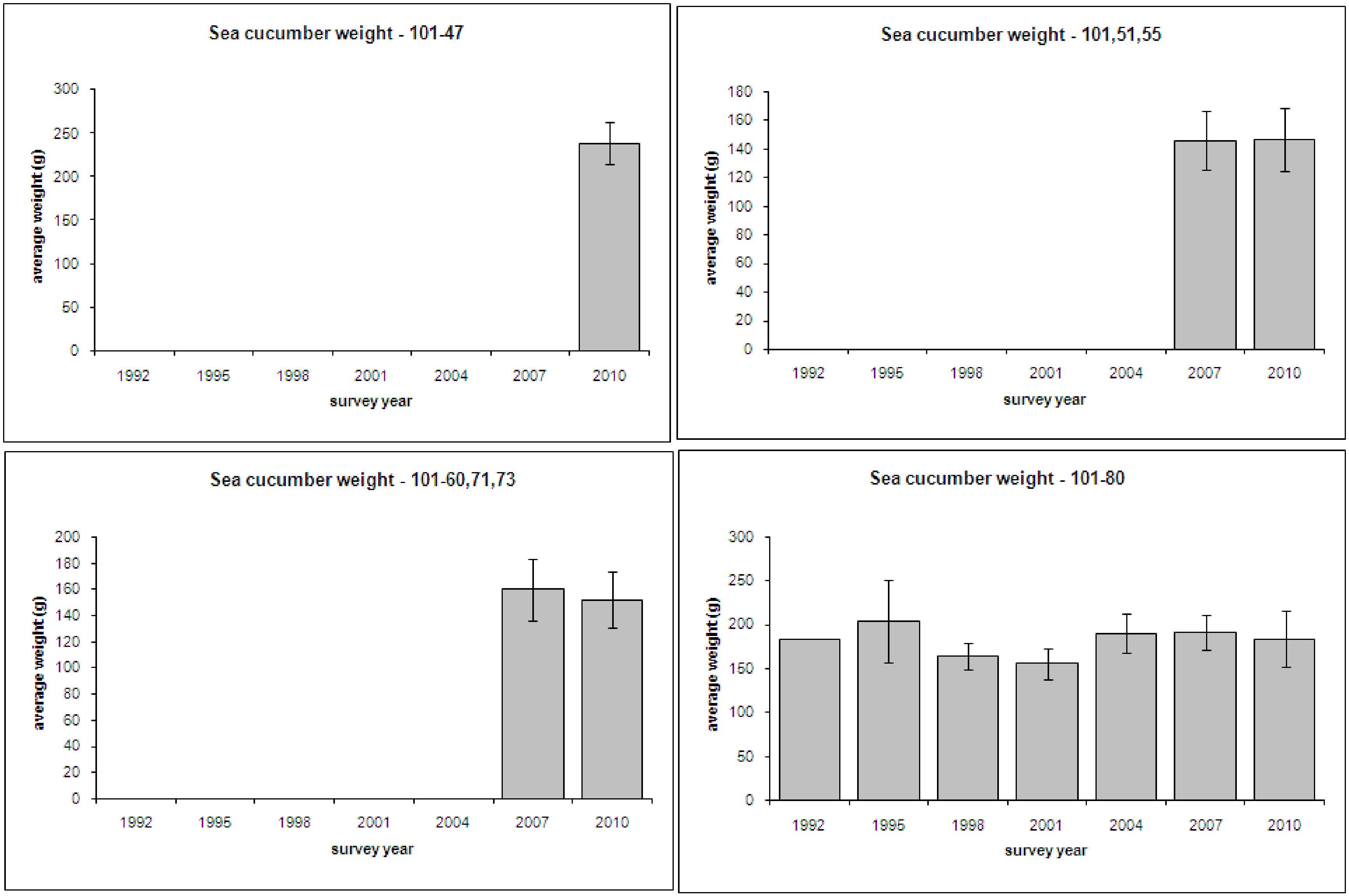


Figure 12.–Average sea cucumber weight (grams) from surveys in commercial fishery Subdistrict 101-47, Subdistricts 101-51,55, Subdistricts 101-60,71,73, and Subdistrict 101-80 in Southeast Alaska. Error bars represent 90% confidence intervals.

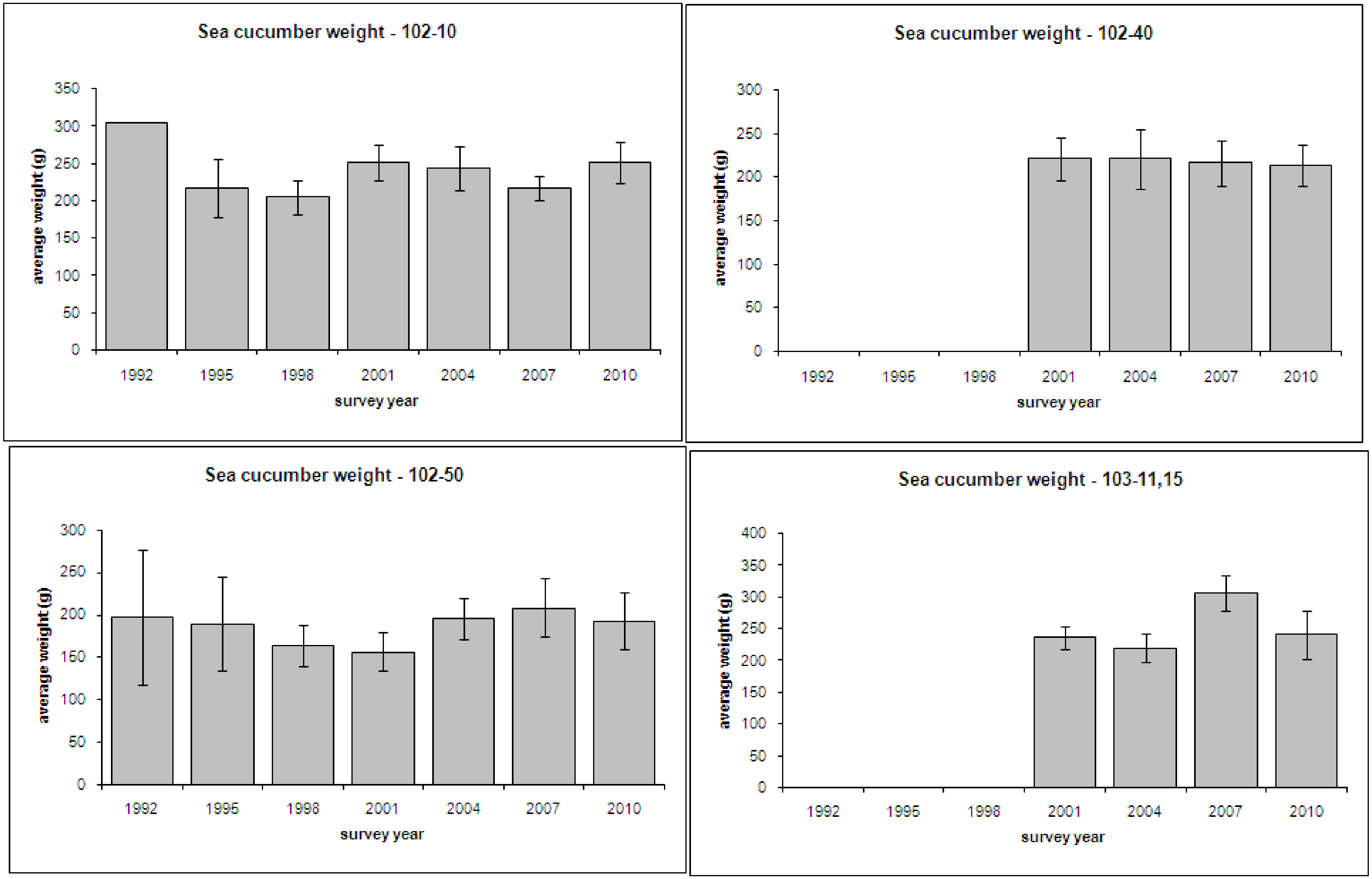


Figure 13.–Average sea cucumber weight (grams) from surveys in commercial fishery Subdistrict 102-10, Subdistrict 102-40, Subdistrict 102-50, and Subdistricts 103-11,15, in Southeast Alaska. Error bars represent 90% confidence intervals.

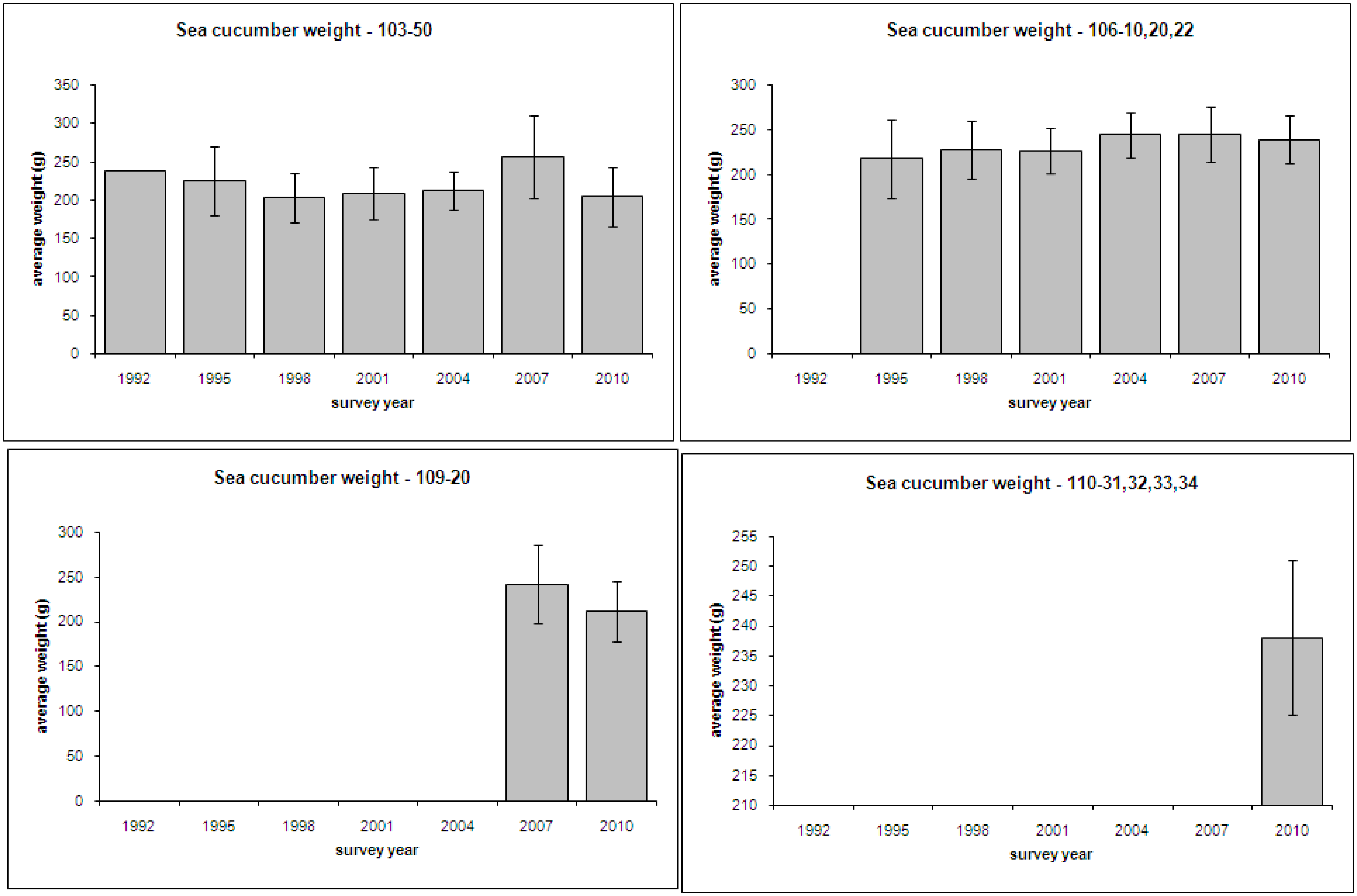


Figure 14.–Average sea cucumber weight from surveys in commercial fishery Subdistrict 103-50, Subdistricts 106-10,20,22, Subdistrict 109-20, and Subdistricts 110-31,32,33,34, in Southeast Alaska. Error bars represent 90% confidence intervals.

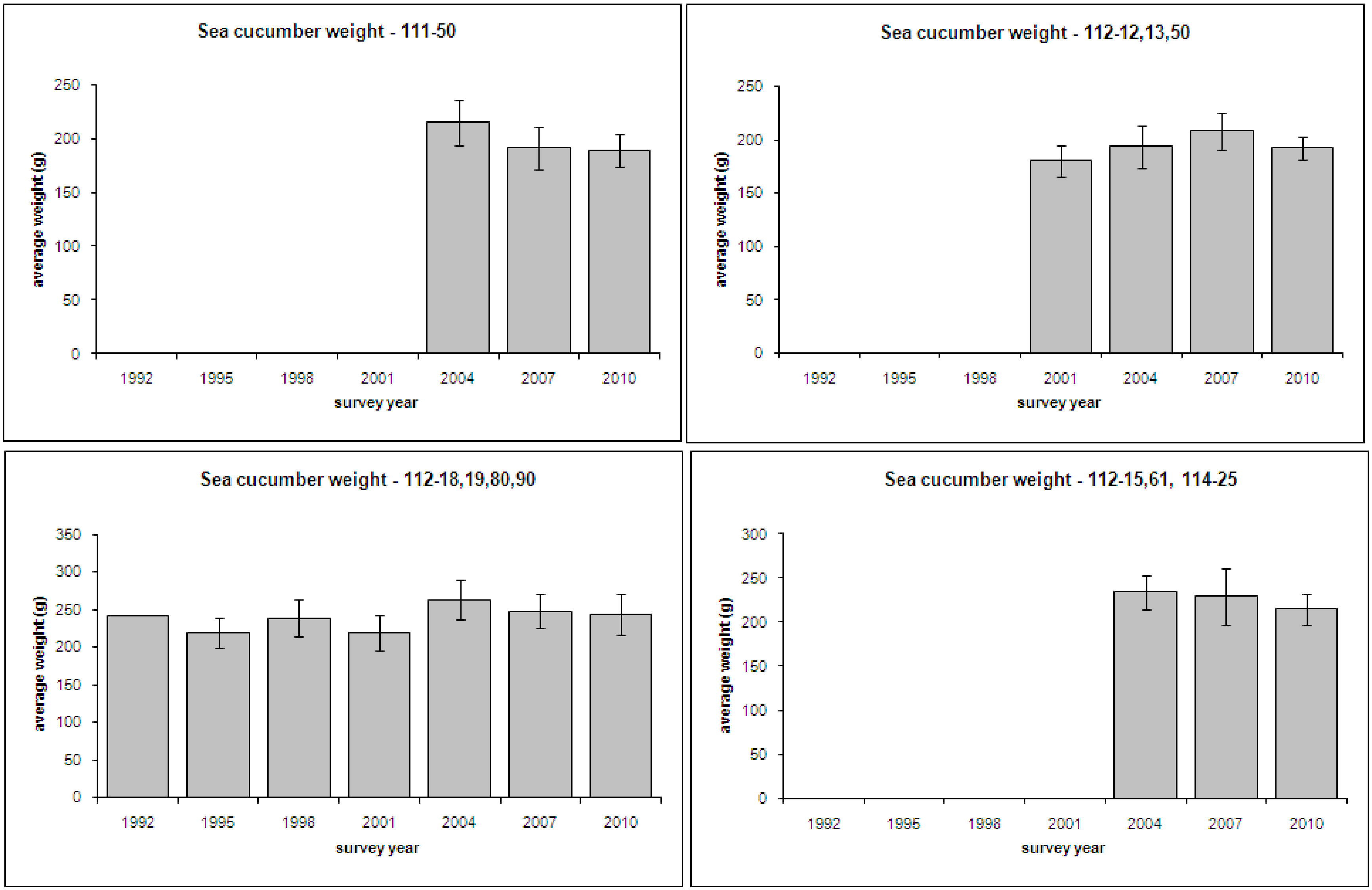


Figure 15.–Average sea cucumber weight (grams) from surveys in commercial fishery Subdistrict 111-50, -11 and Subdistricts 112-12,13,50, Subdistricts 112-18,19,80,90, and Subdistricts 112-15,61,114-25, in Southeast Alaska. Error bars represent 90% confidence intervals.

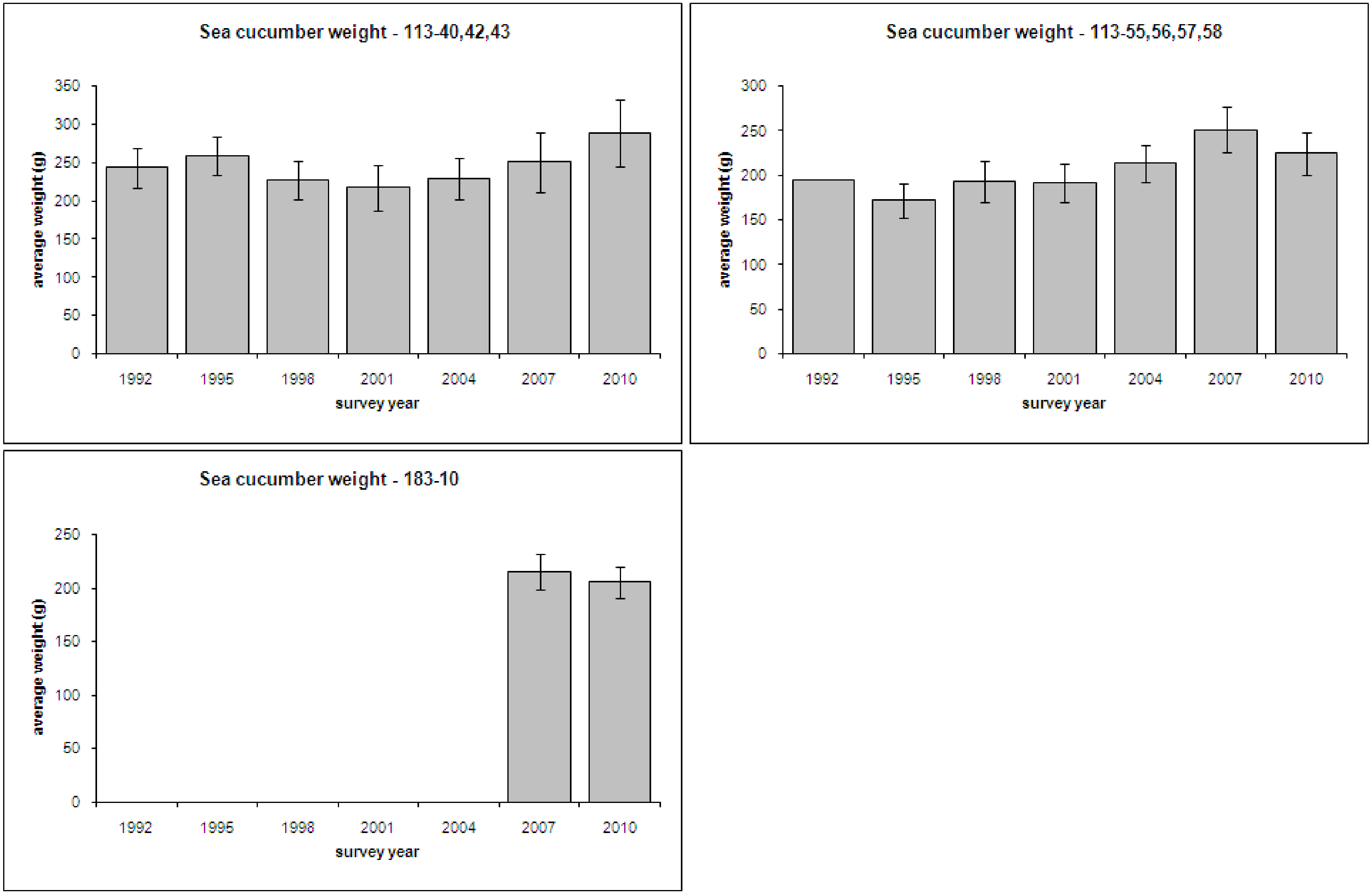


Figure 16.–Average sea cucumber weight (grams) from surveys in commercial fishery Subdistricts 113-40,42,43, Subdistricts 113-55,56,57,58, and Subdistrict 183-10, in Southeast Alaska. Error bars represent 90% confidence intervals.

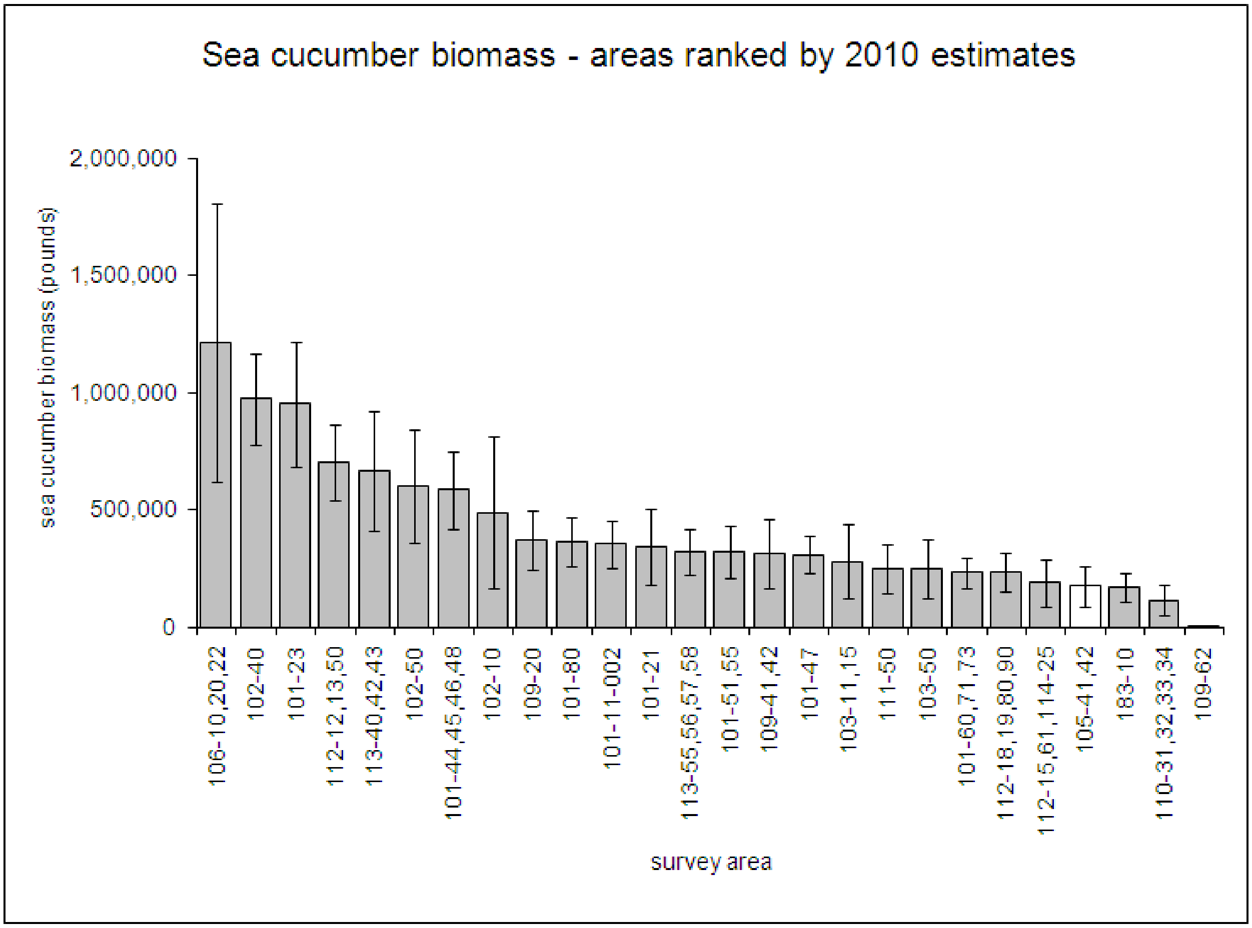


Figure 17.–Estimated sea cucumber biomass (ranked using 2010 results) in Southeast Alaska. Bars with no shading represent values from surveys prior to 2010, as no survey was conducted in 2010 and are shown for comparison. Error bars represent 90% confidence intervals.

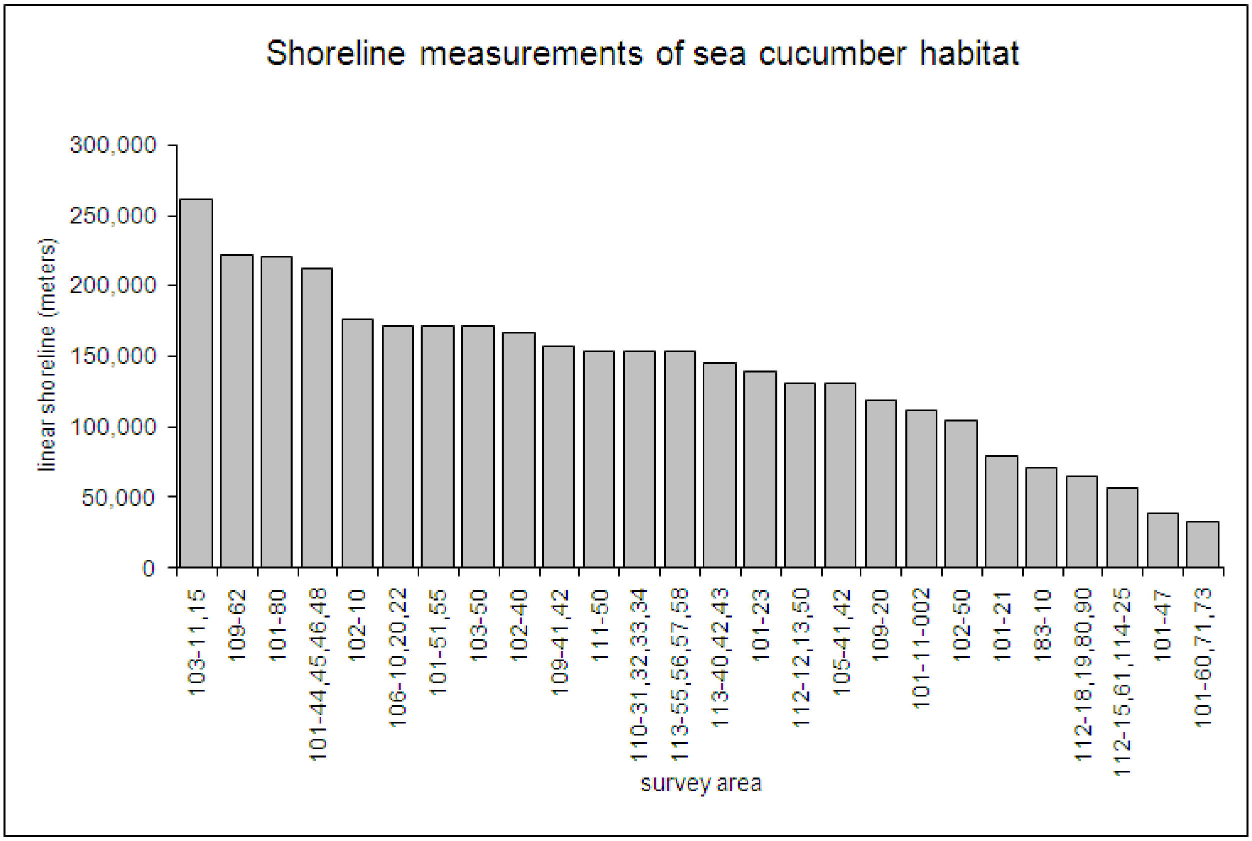


Figure 18.–Measurements of estimated sea cucumber habitat shoreline in Southeast Alaska.

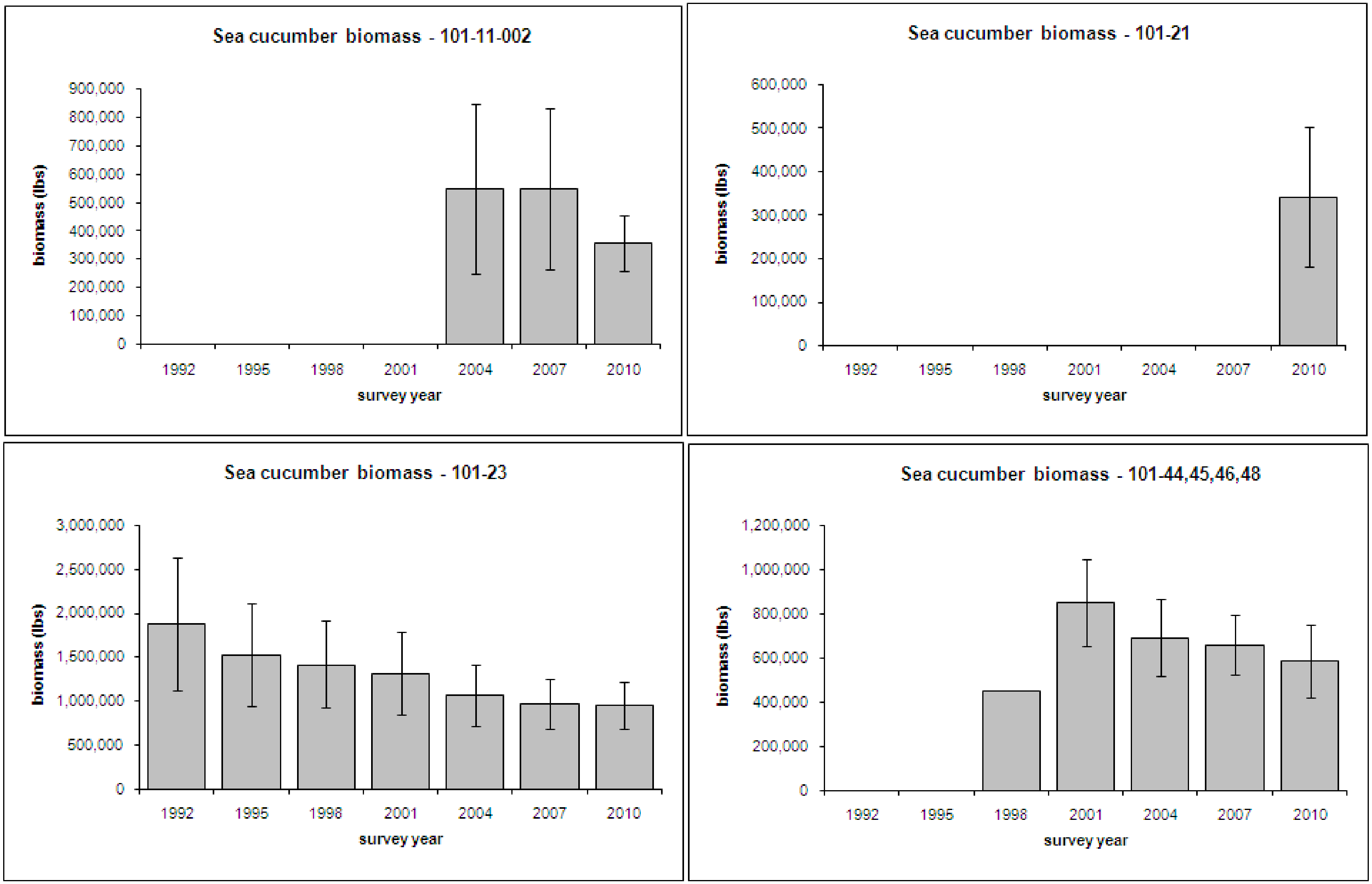


Figure 19.–Total sea cucumber biomass (pounds) from surveys in commercial fishery Subdistrict 101-11-002, Subdistrict 101-21, Subdistrict 101-23, and Subdistricts 101-44,45,46,48, in Southeast Alaska. Error bars represent 90% confidence intervals.

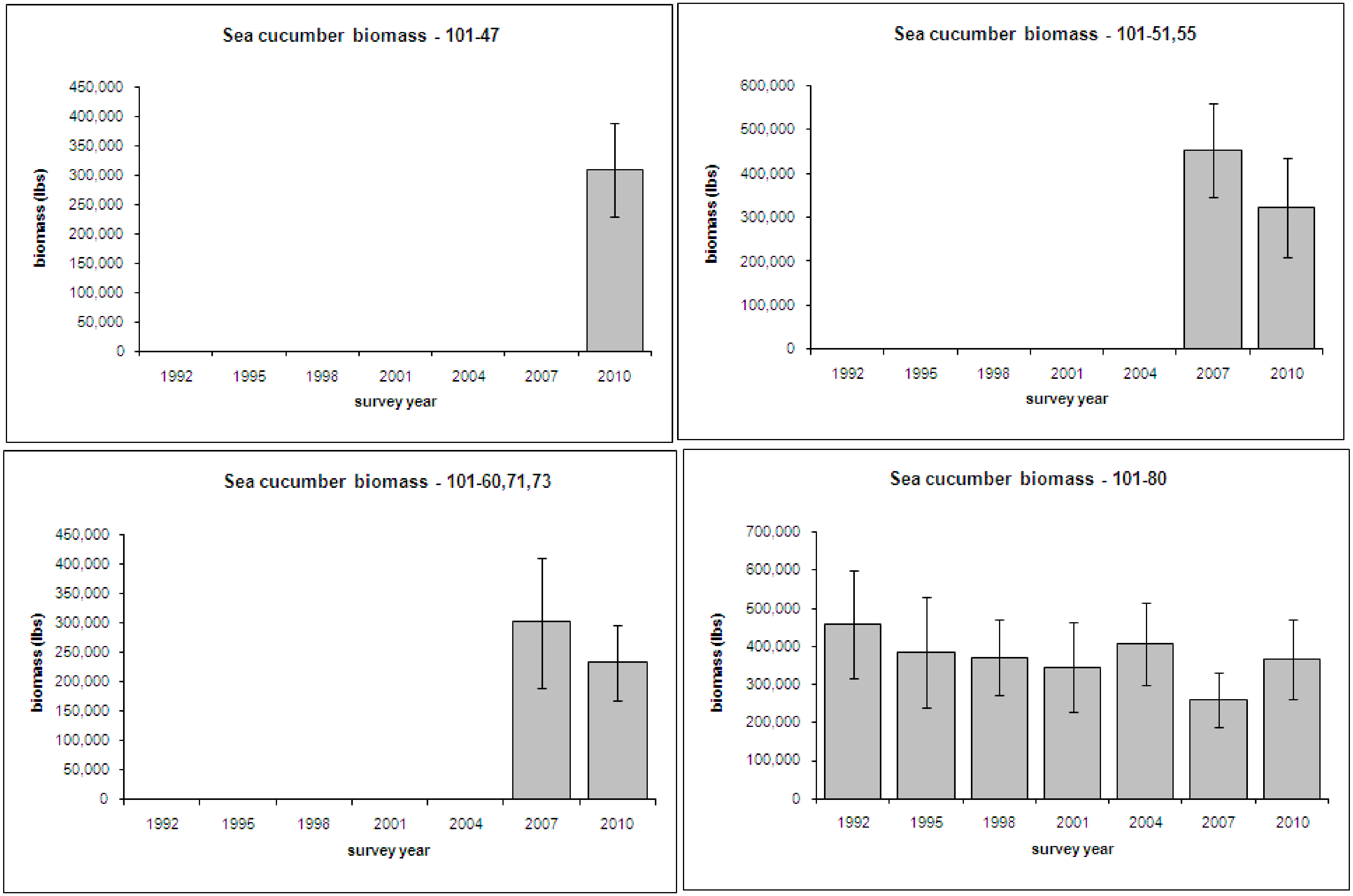


Figure 20.–Total sea cucumber biomass (pounds) from surveys in commercial fishery Subdistrict 101-47, Subdistricts 101-51,55, Subdistricts 101-60,71,73, and Subdistrict 101-80, in Southeast Alaska. Error bars represent 90% confidence intervals.

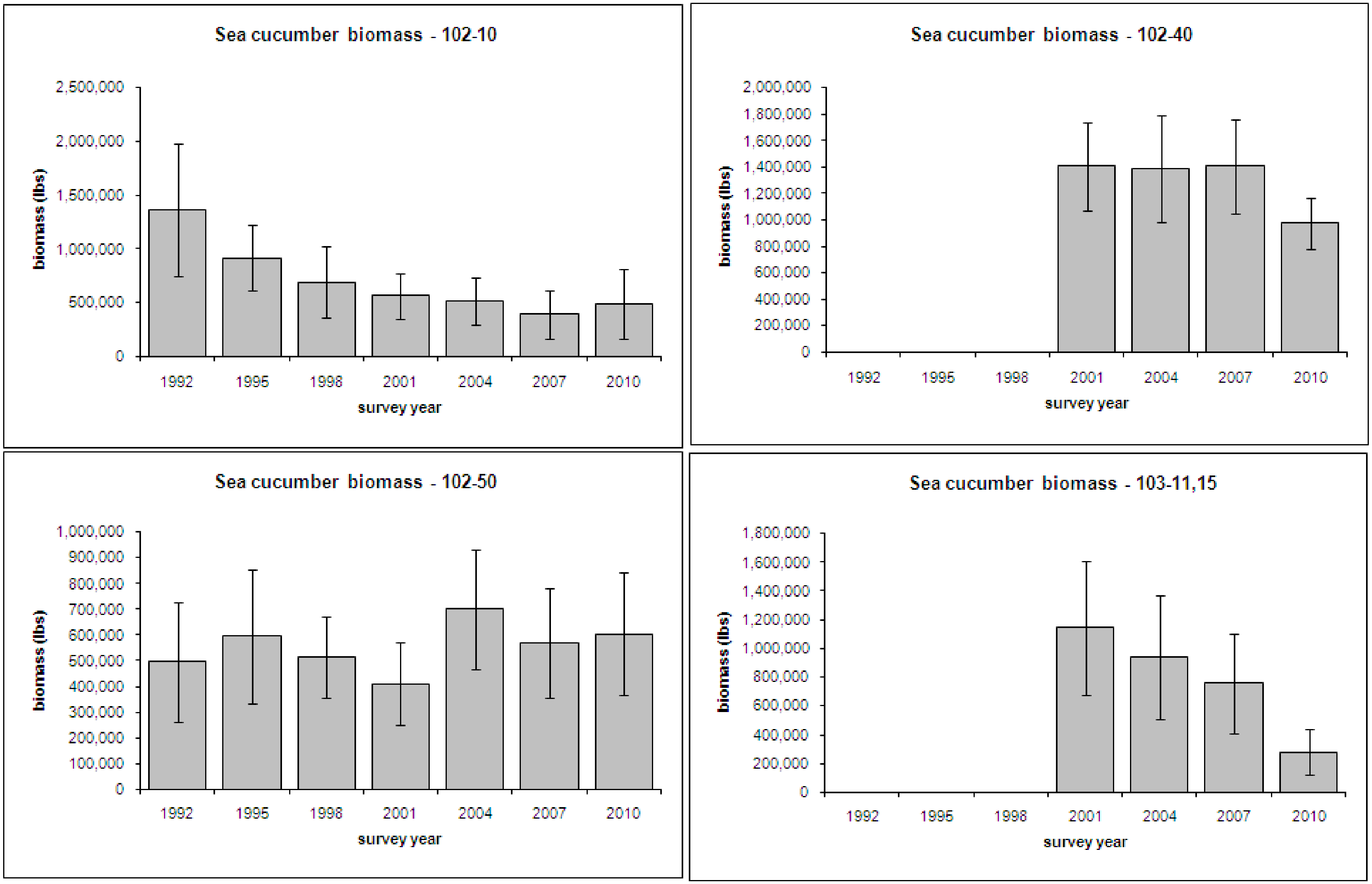


Figure 21.–Total sea cucumber biomass (pounds) from surveys in commercial fishery Subdistrict 102-10, Subdistrict 102-40, Subdistrict 102-50, and Subdistricts 103-11,15, in Southeast Alaska. Error bars represent 90% confidence intervals.

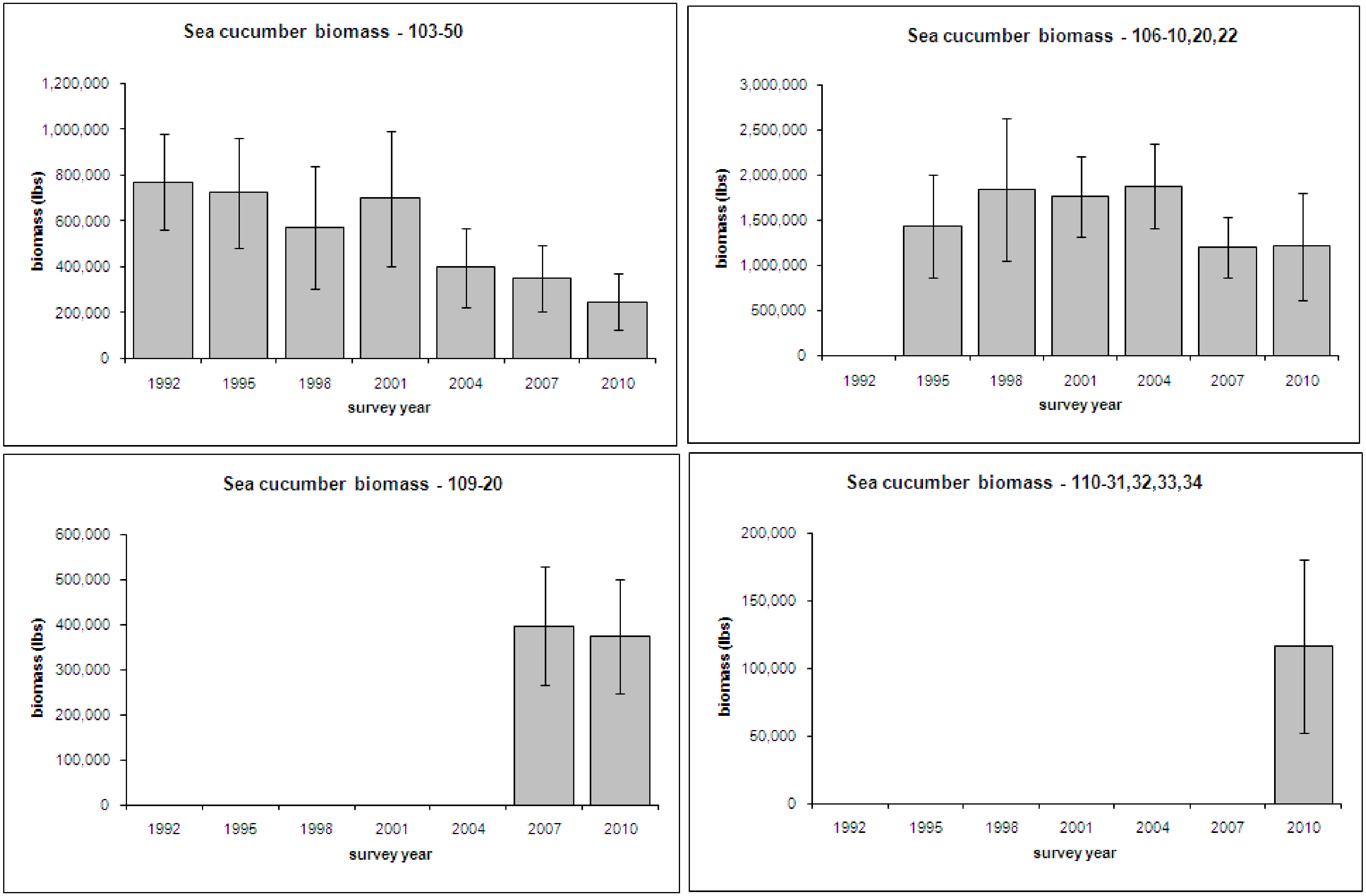


Figure 22.–Total sea cucumber biomass (pounds) from surveys in commercial fishery Subdistrict 103-50, Subdistricts 106-10,20,22, Subdistrict 109-20, and Subdistricts 110-31,32,33,34, in Southeast Alaska. Error bars represent 90% confidence intervals.

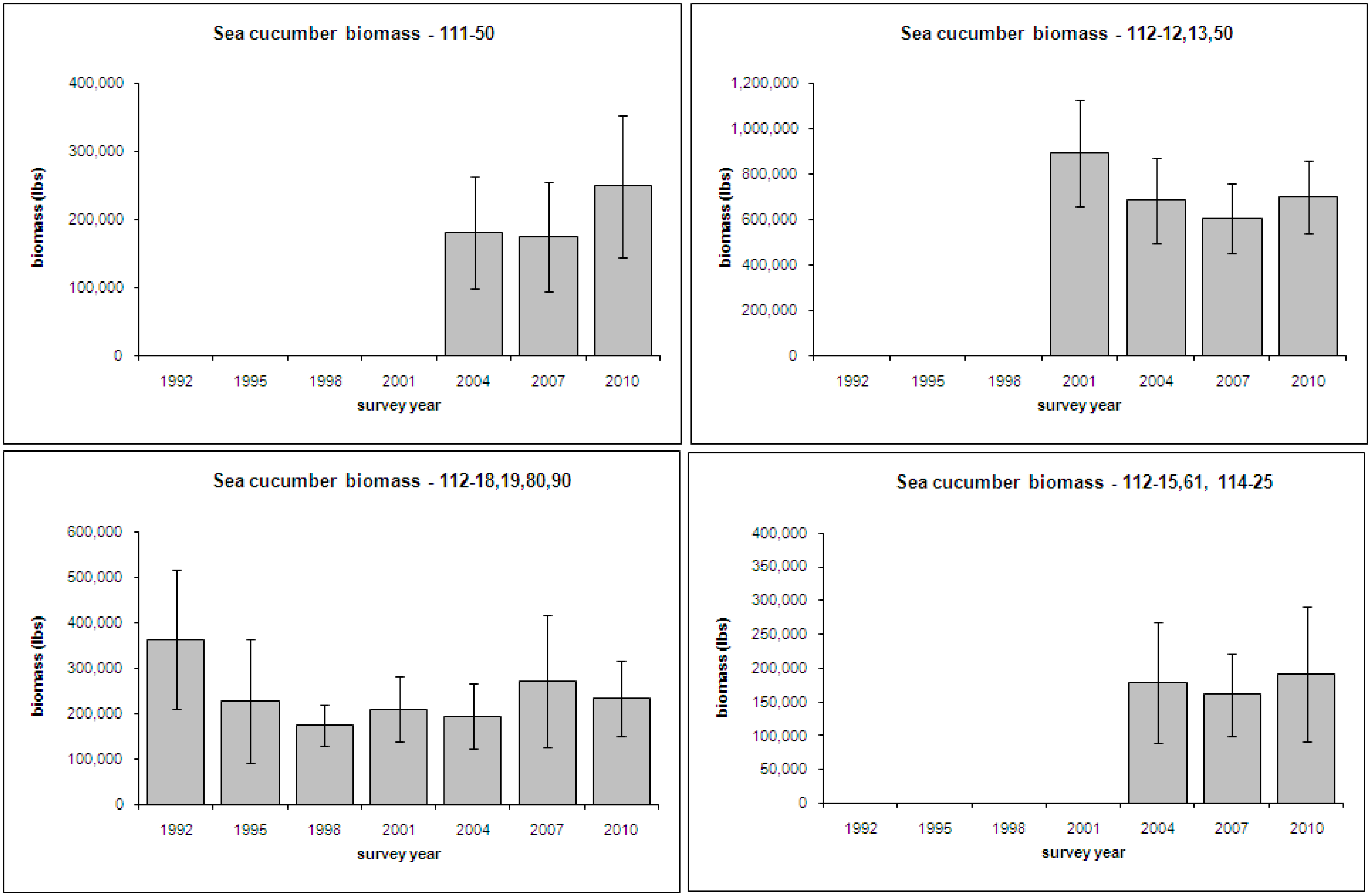


Figure 23.–Total sea cucumber biomass (pounds) from surveys in commercial fishery Subdistrict 111-50, Subdistricts 112-12,13,50, Subdistricts 112-18,19,80,90, and Subdistricts 112-15,61,114-25, in Southeast Alaska. Error bars represent 90% confidence intervals.

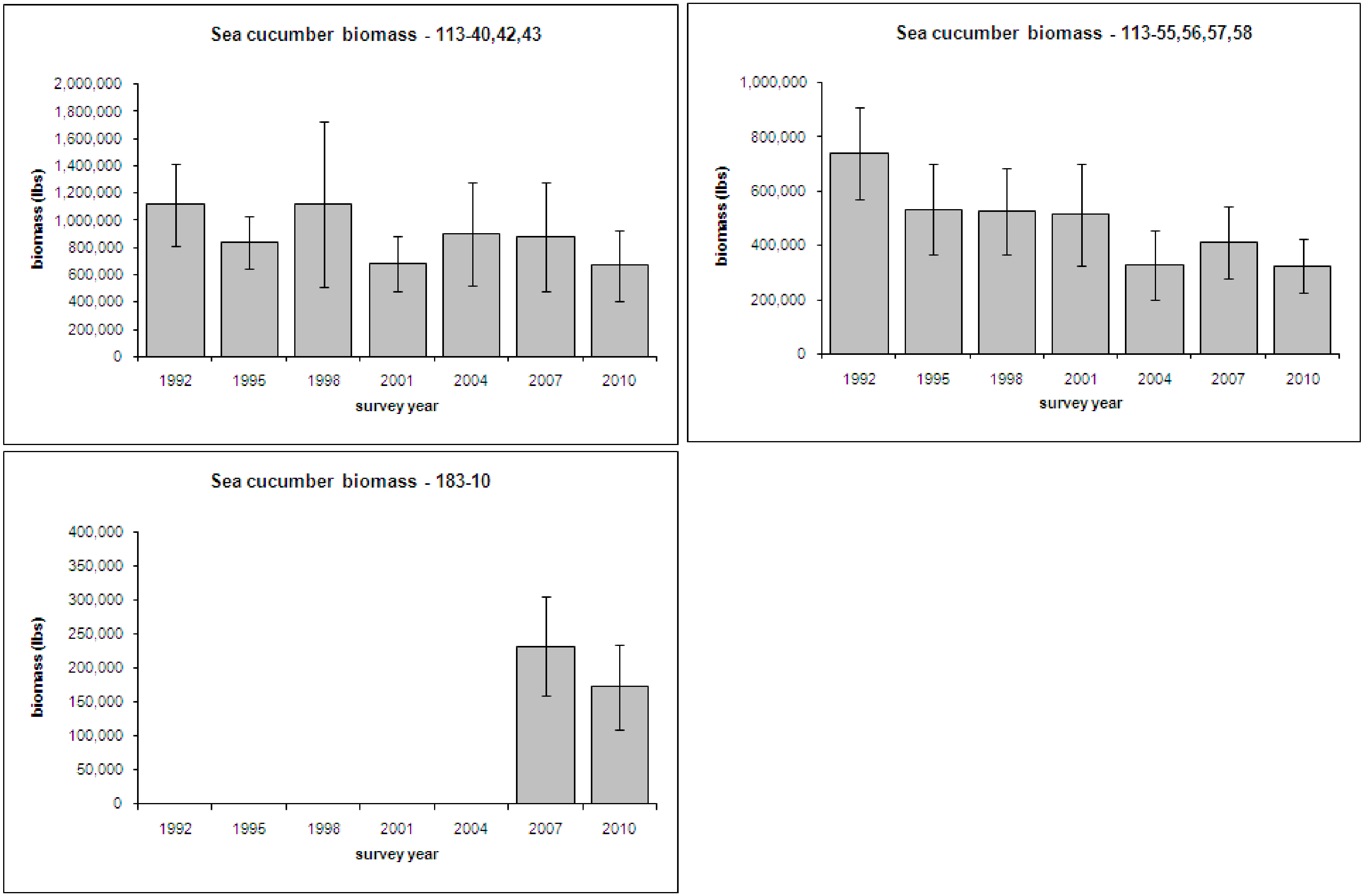


Figure 24.–Total sea cucumber biomass (pounds) from surveys in commercial fishery Subdistricts 113-40,42,43, Subdistricts 113-55,56,57,58, and Subdistrict 183-10, in Southeast Alaska. Error bars represent 90% confidence intervals.

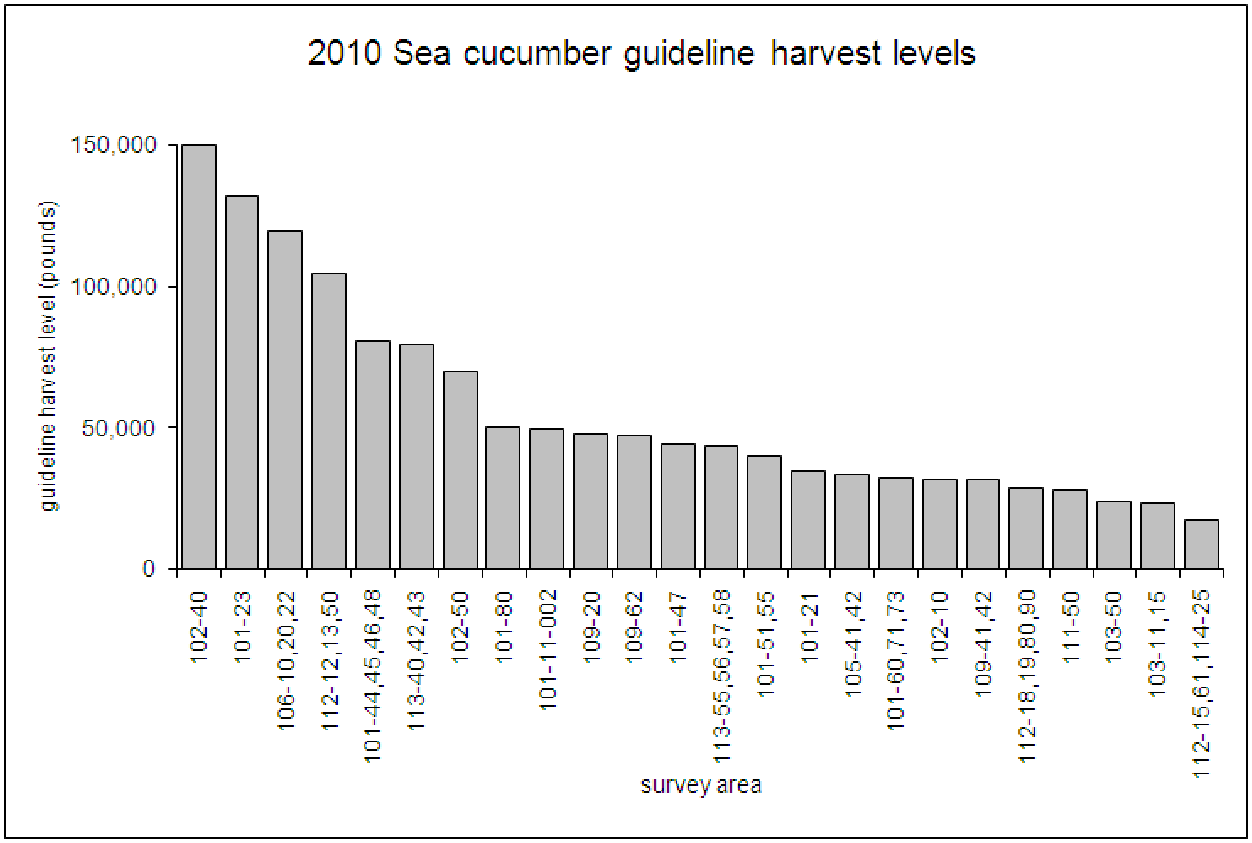


Figure 25.–Sea cucumber commercial fishery guideline harvest levels established for the 2010/2011 fishing season.

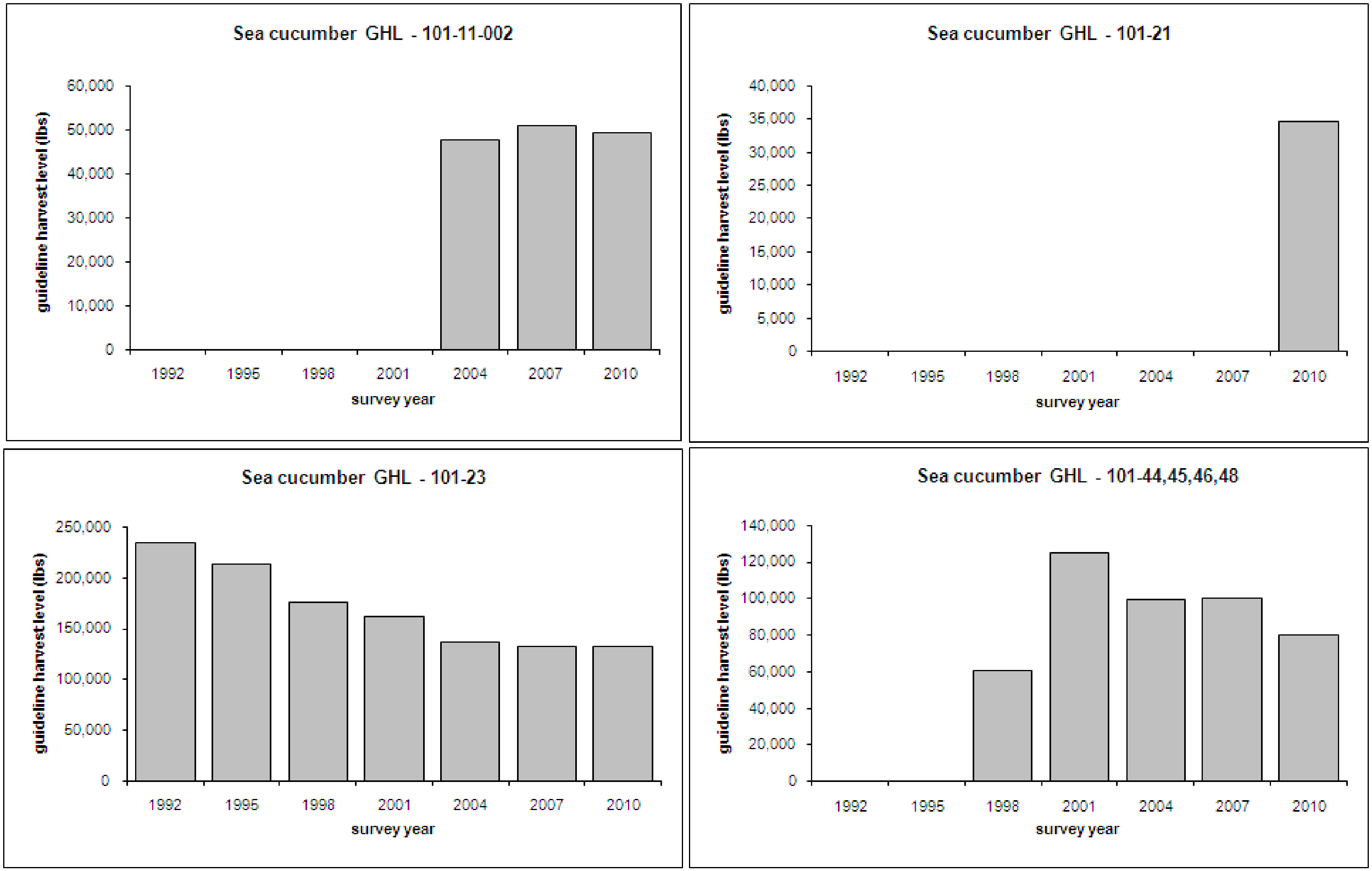


Figure 26.–Actual commercial fishery guideline harvest levels (GHLs) in pounds for fishery Subdistrict 101-11-002, Subdistrict 101-21, Subdistrict 101-23, and Subdistricts 101-44,45,46,48, in Southeast Alaska.

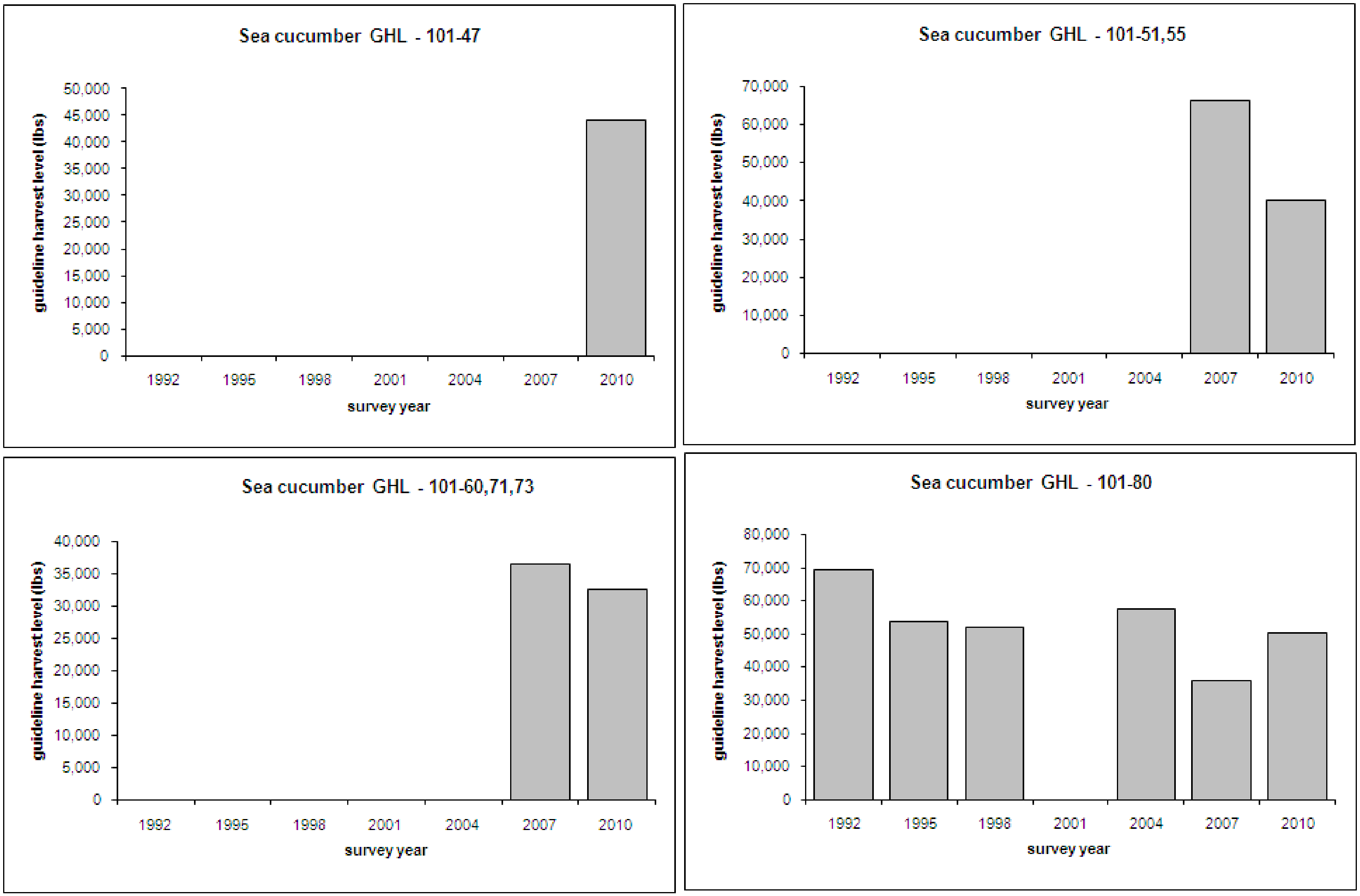


Figure 27.–Actual commercial fishery guideline harvest levels (GHLs) in pounds for fishery Subdistrict 101-47, Subdistricts 101-51,55, Subdistricts 101-60,71,73, and Subdistrict 101-80, in Southeast Alaska.

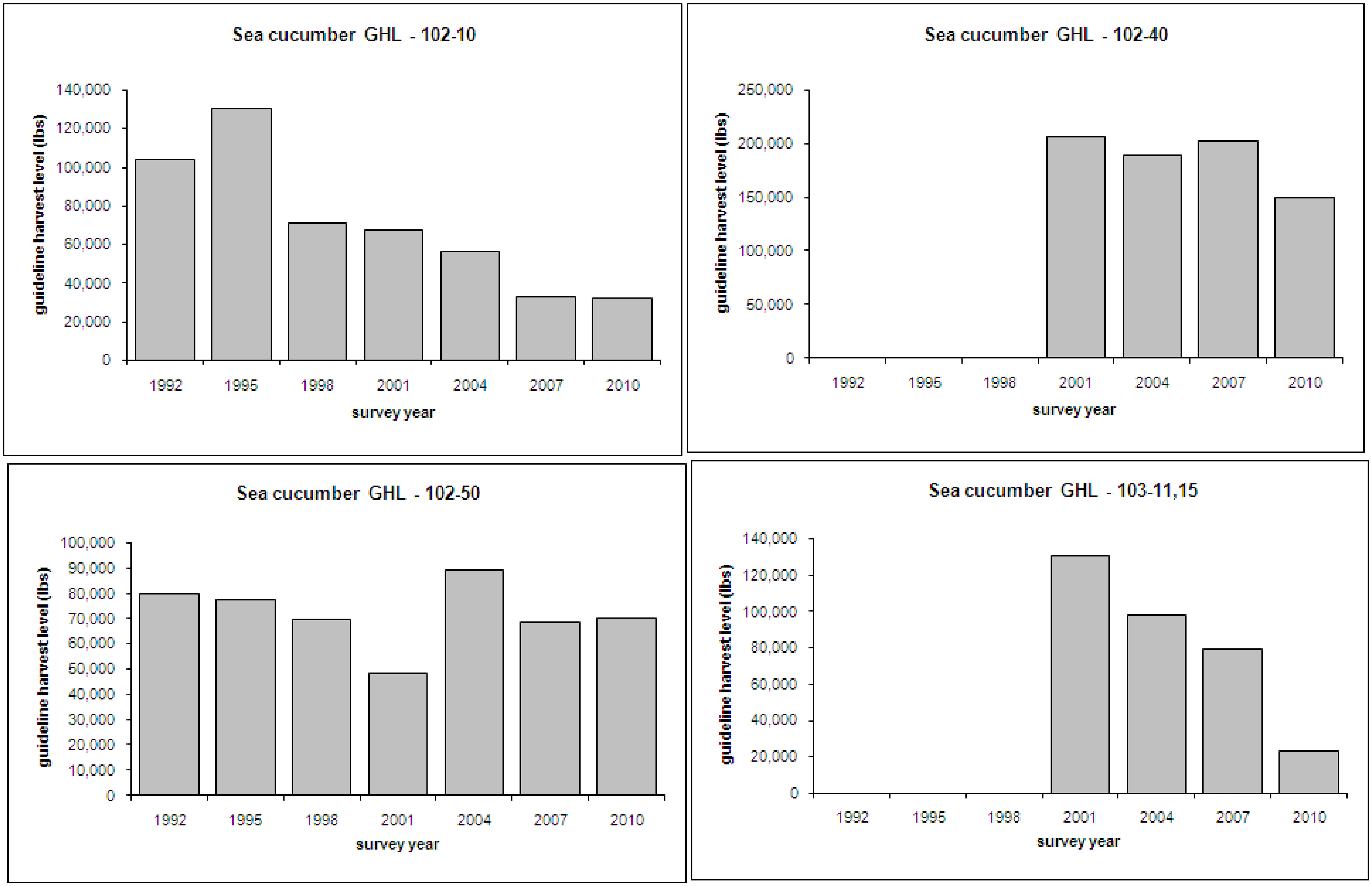


Figure 28.–Actual commercial fishery guideline harvest levels (GHLs) in pounds for fishery Subdistrict 102-10, Subdistrict 102-40, Subdistrict 102-50, and Subdistricts 103-11,15, in Southeast Alaska.

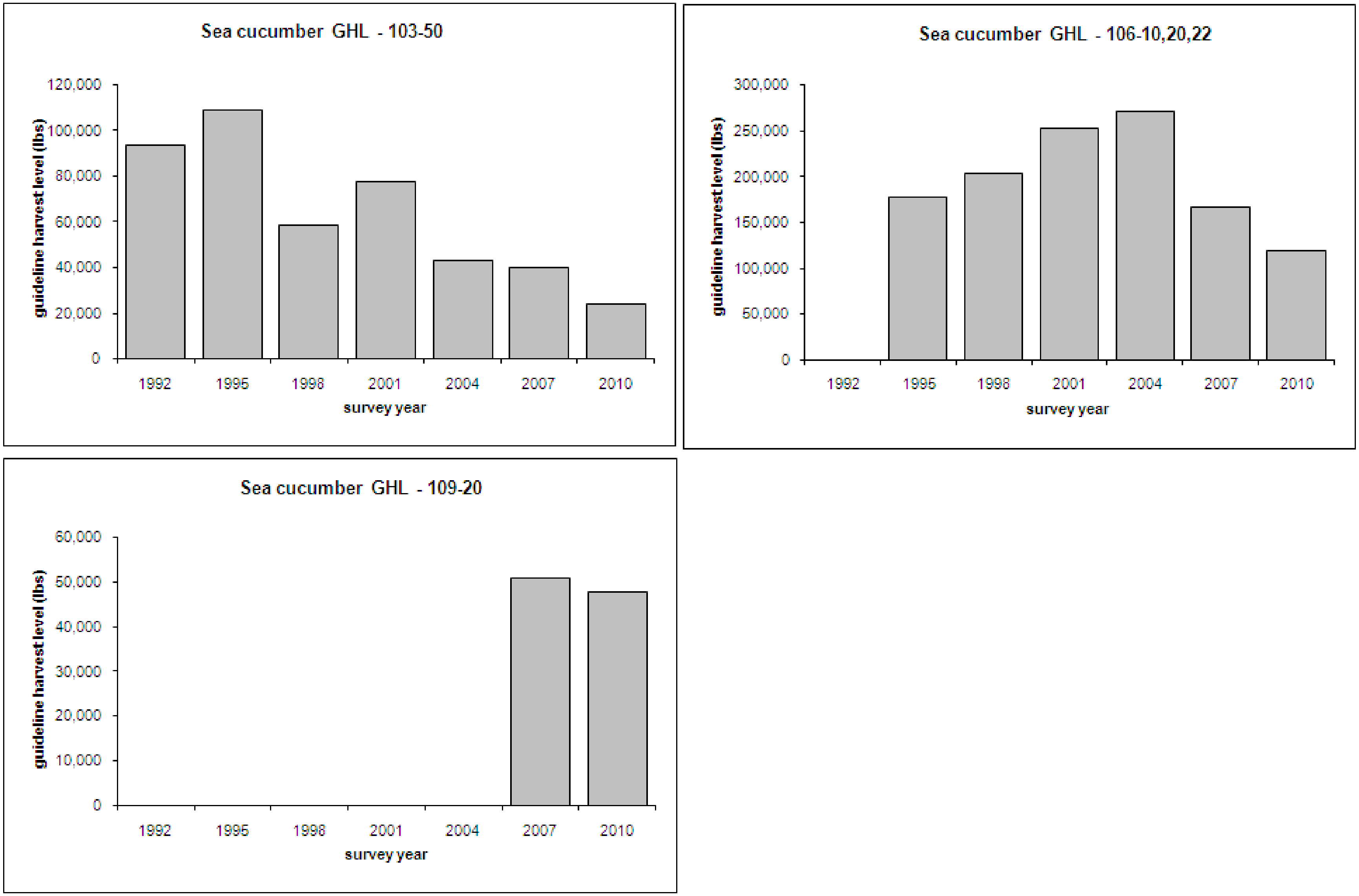


Figure 29.–Actual commercial fishery guideline harvest levels (GHLs) in pounds for fishery Subdistrict 103-50, Subdistricts 106-10,20,22, and Subdistrict 109-20, in Southeast Alaska.

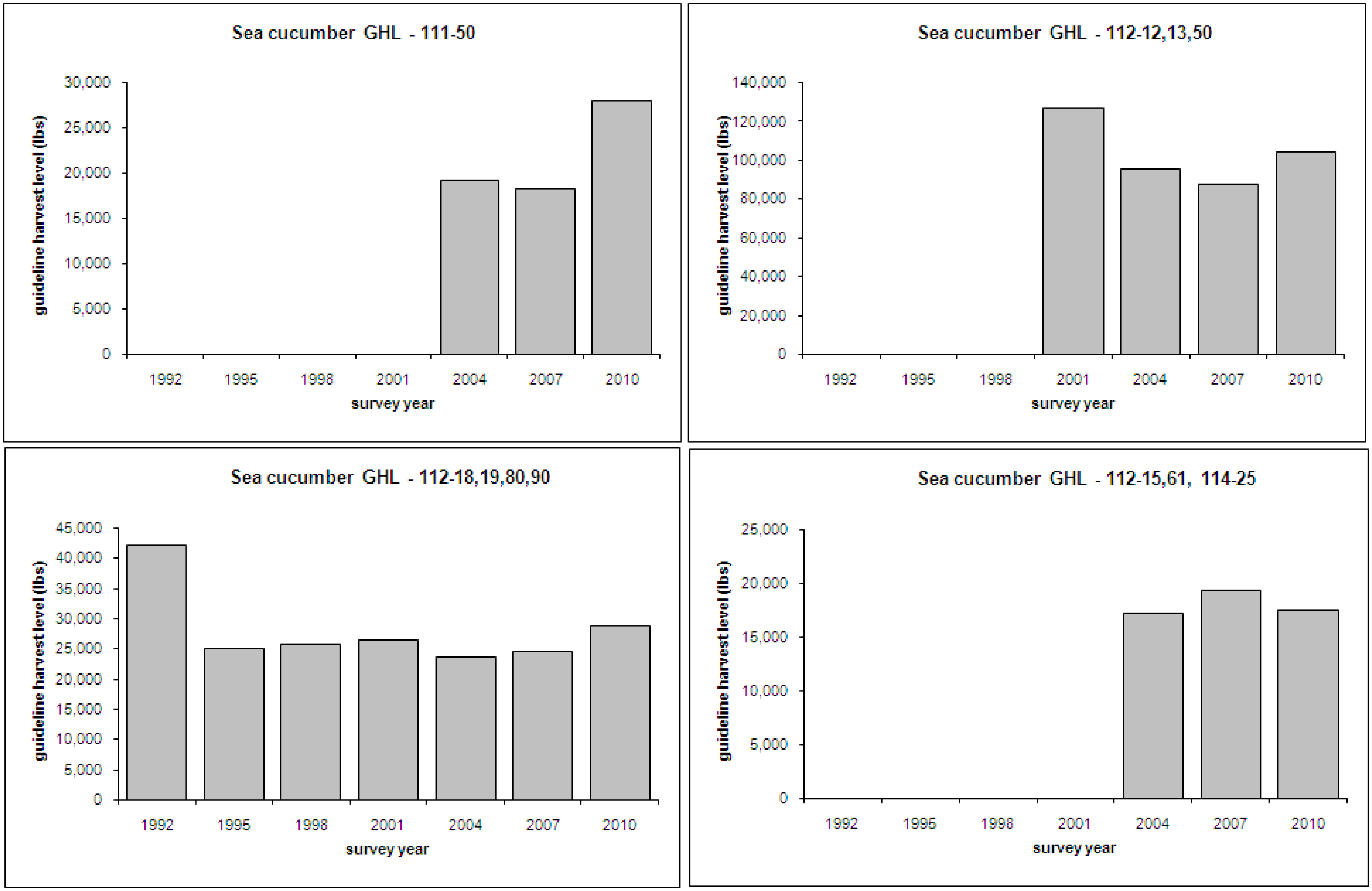


Figure 30.–Actual commercial fishery guideline harvest levels (GHLs) in pounds for fishery Subdistrict 111-50, Subdistricts 112-12,13,50, Subdistricts 112-18,19,80,90, and Subdistricts 112-15,61,114-25, in Southeast Alaska.

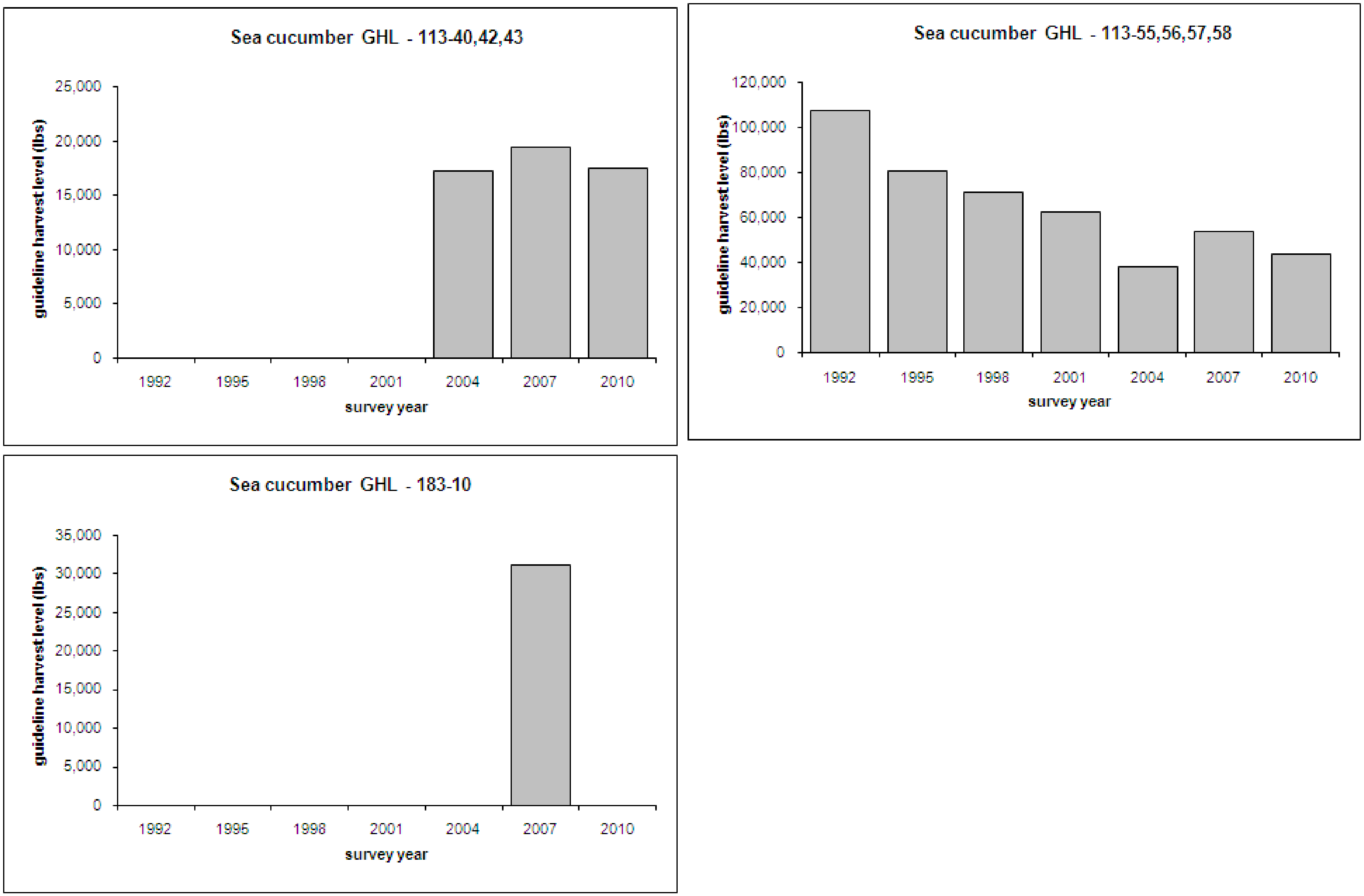


Figure 31.–Actual commercial fishery guideline harvest levels (GHLs) in pounds for fishery Subdistricts 113-40,42,43, Subdistricts 113-55,56,57,58, and Subdistrict 183-10, in Southeast Alaska.

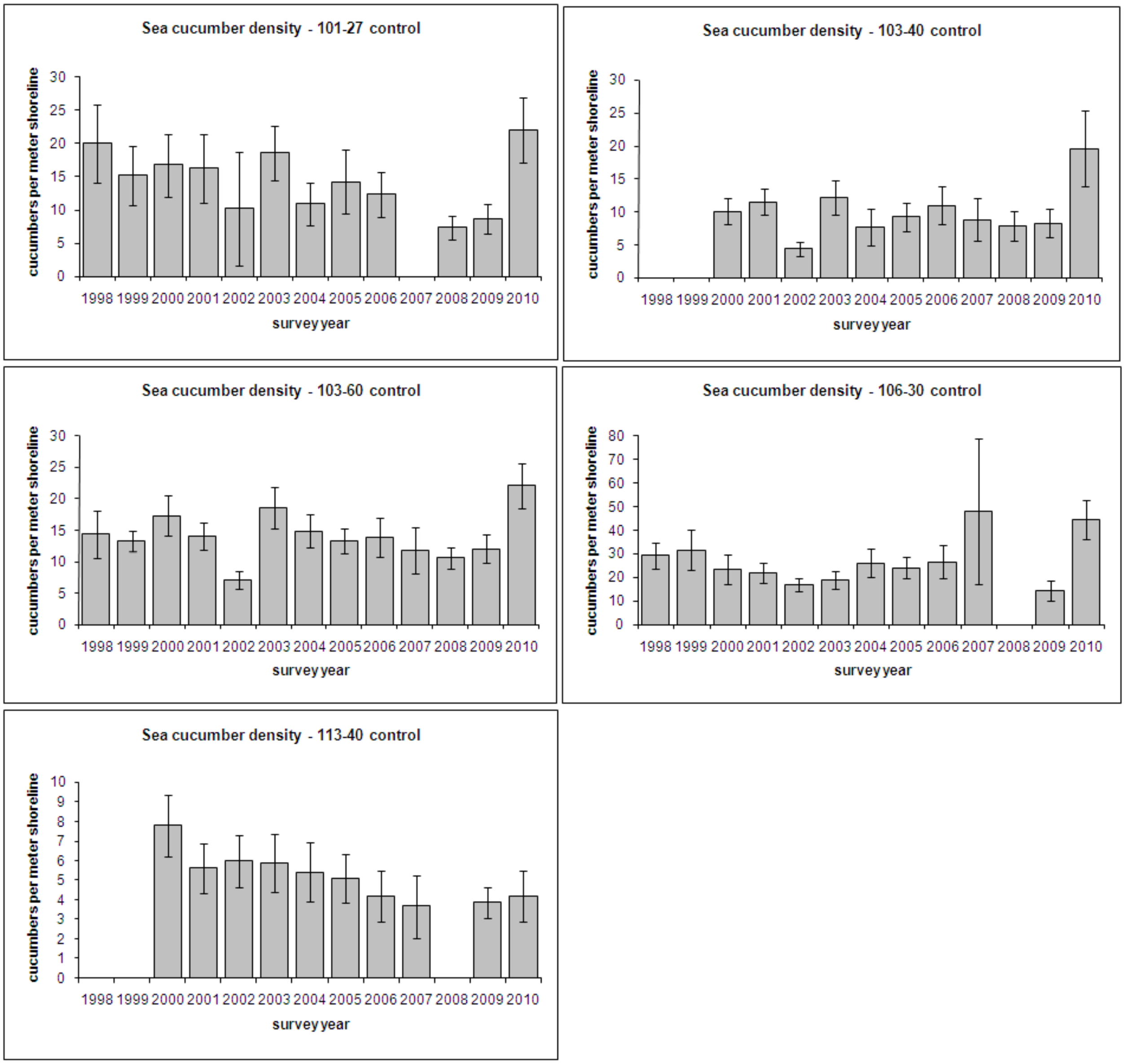


Figure 32.–Average number of sea cucumbers per meter of shoreline from surveys in control area (closed to commercial harvest) Subdistrict 101-27, Subdistrict 103-40, Subdistrict 103-60, Subdistrict 106-30, and Subdistrict 113-41 in Southeast Alaska. Error bars represent 90% confidence intervals.

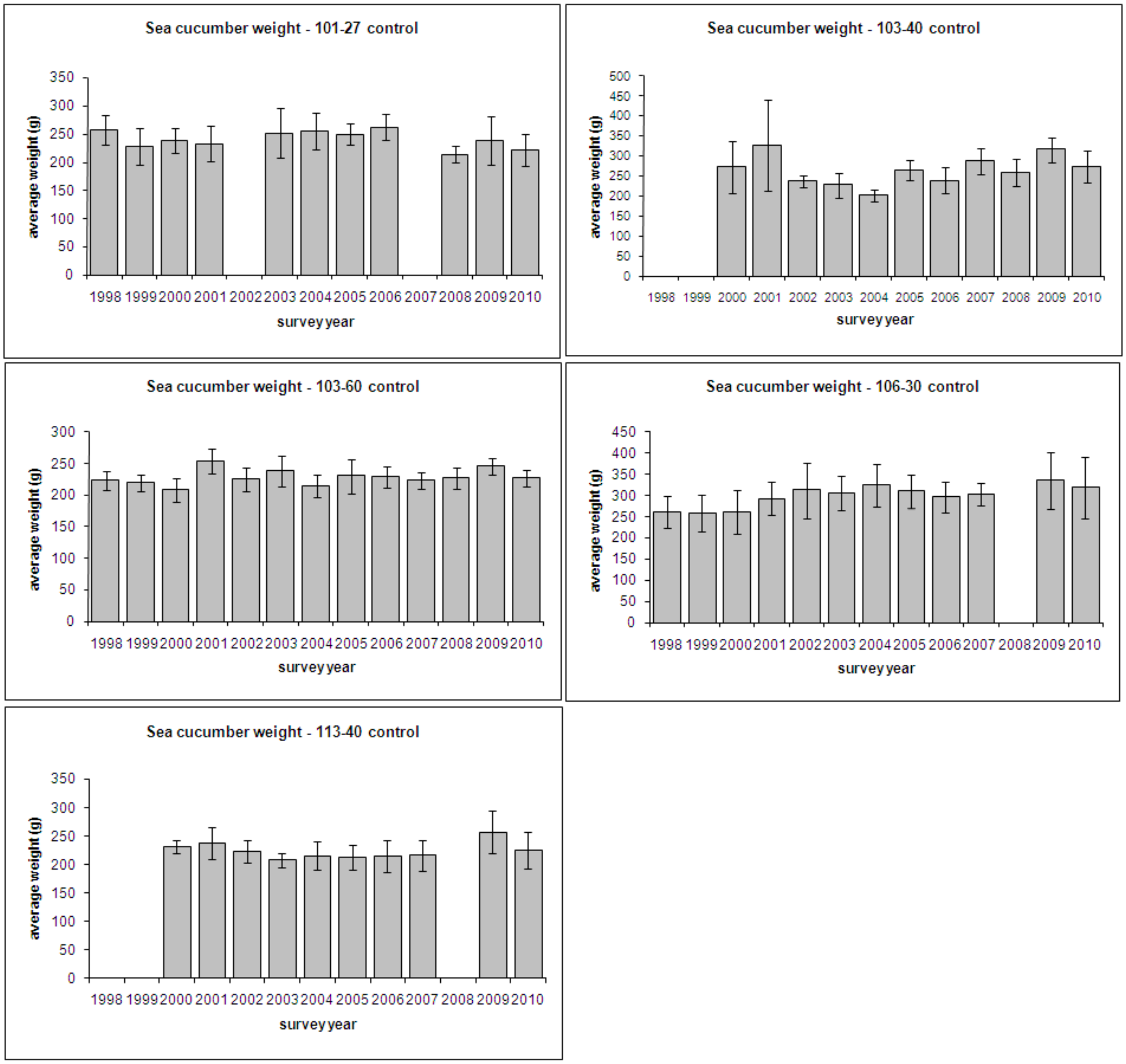


Figure 33.–Average sea cucumbers weight (grams) from surveys in control area (closed to commercial harvest) Subdistrict 101-27, Subdistrict 103-40, Subdistrict 103-60, Subdistrict 106-30, and Subdistrict 113-41 in Southeast Alaska. Error bars represent 90% confidence intervals.

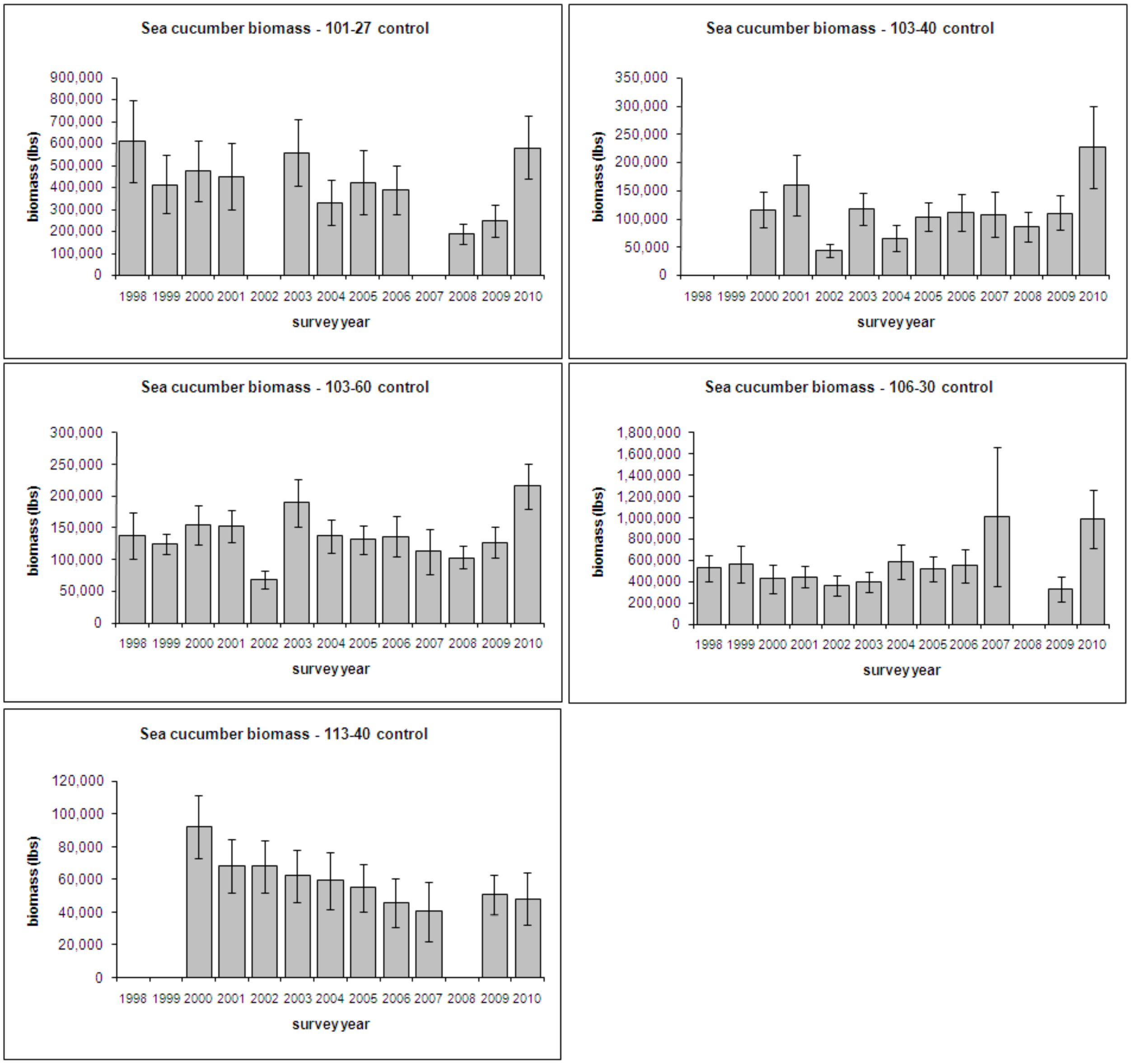


Figure 34.–Total sea cucumber biomass (pounds) from surveys in control area (closed to commercial harvest) Subdistrict 101-27, Subdistrict 103-40, Subdistrict 103-60, Subdistrict 106-30, and Subdistrict 113-41 in Southeast Alaska. Error bars represent 90% confidence intervals.

APPENDIX A: KEY TO SUBSTRATE TYPES

Appendix A1.–Key to vegetative substrate types used for herring spawn deposition survey.

Code	Expanded code	Species included	Latin names
AGM	Agarum	Sieve kelp	*Agarum clathratum*
ALA	Alaria	Ribbon kelps	*Alaria marginata, A. nana, A. fistulosa*
ELG	Eel grass	Eel grass, surfgrasses	*Zostera marina, Phyllospadix serrulatus, P. scouleri*
FIL	Filamentous algae	Sea hair	*Enteromorpha intestinalis*
FIR	Fir kelp	Black pine, Oregon pine (red algae)	*Neorhodomela larix, N.oregona*
FUC	Fucus	Rockweed	*Fucus gardneri*
HIR	Hair kelp	Witch’s hair, stringy acid kelp	*Desmarestia aculeata, D. viridis*
LAM	Laminaria	split kelp, sugar kelp, suction-cup kelp	*Laminaria bongardiana, L. saccharina, L. yezoensis (when isolated and identifiable)*
LBK	Large Brown Kelps	5-ribbed kelp, 3-ribbed kelp, split kelp, sugar kelp, sea spatula, sieve kelp, ribbon kelp	*Costaria costata, Cymathere triplicata, Laminaria spp., Pleurophycus gardneri, Agarum, Alaria spp.*
MAC	Macrocystis	Small perennial kelp	*Macrocystis sp.*
NER	Nereocystis	Bull kelp	*Nereocystis leutkeana*
RED	Red algae	All red leafy algae (red ribbons, red blades, red sea cabbage, Turkish washcloth)	*Palmaria mollis, P. hecatensis, P. callophylloides, Dilsea californica, Neodilsea borealis, Mastocarpus papillatus, Turnerella mertensiana*
ULV	Ulva	Sea lettuce	*Ulva fenestrata, Ulvaria obscura*
COR	Coralline algae	Coral seaweeds (red algae)	*Bossiella, Corallina, Serraticardia*

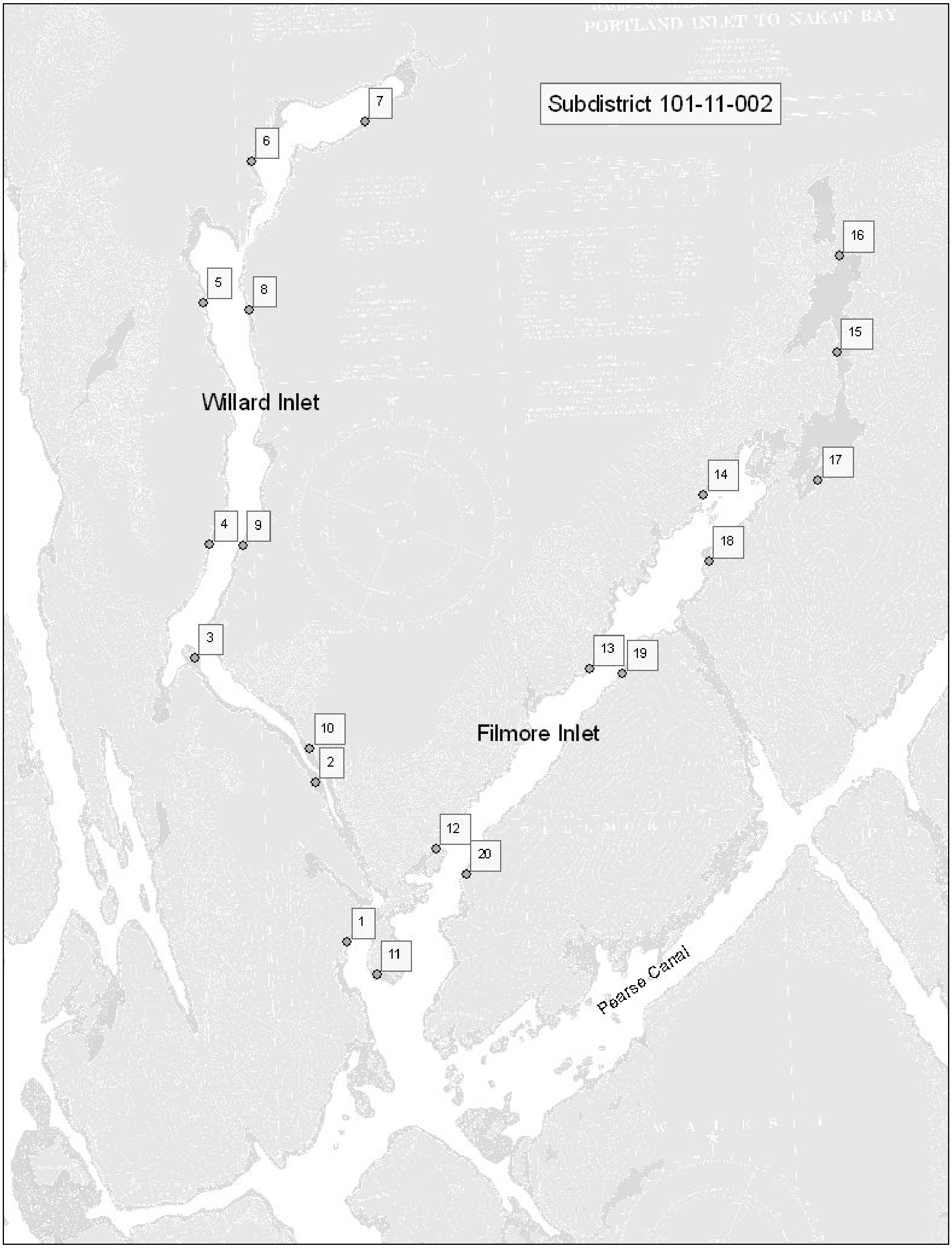
APPENDIX B: KEY TO BOTTOM TYPES

Appendix B1.–Key to bottom types used for herring spawn deposition survey.

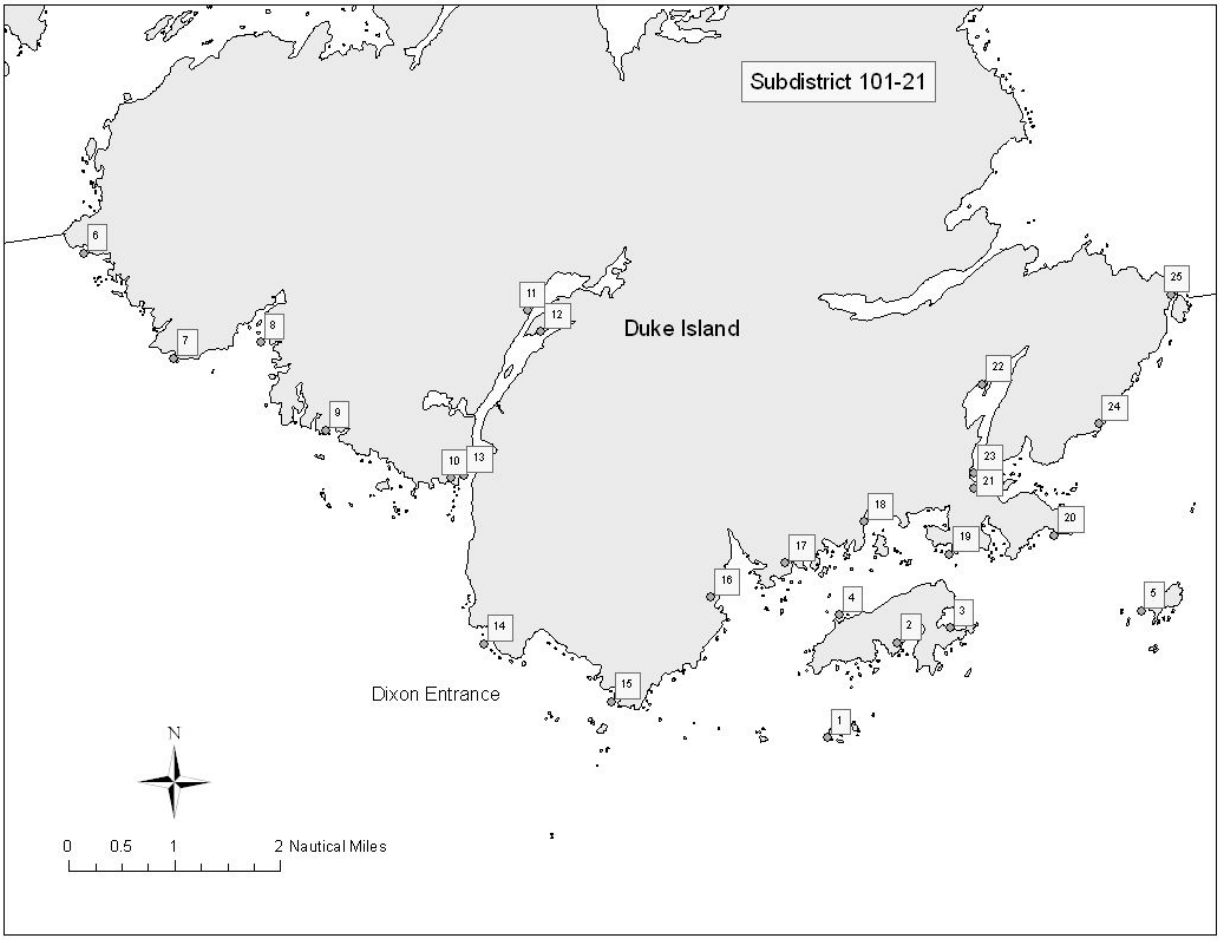
Code	Expanded code	Definition
RCK	Bedrock	Various rocky substrates > 1 m in diameter
BLD	Boulder	Substrate between 25 cm and 1 m
CBL	Cobble	Substrate between 6 cm and 25 cm
GVL	Gravel	Substrate between 0.4 cm and 6 cm
SND	Sand	Clearly separate grains of < 0.4 cm
MUD	Mud	Soft, paste-like material
SIL	Silt	Fine organic dusting (very rarely used)
BAR	Barnacle	Area primarily covered with barnacles
SHL	Shell	Area primarily covered with whole or crushed shells
MUS	Mussels	Area primarily covered with mussels
WDY	Woody debris	Any submerged bark, logs, branches or root systems

APPENDIX C: MAPS DISPLAYING LOCATIONS OF COMMERCIAL FISHERY AREAS TRANSECTS SURVEYED IN 2009

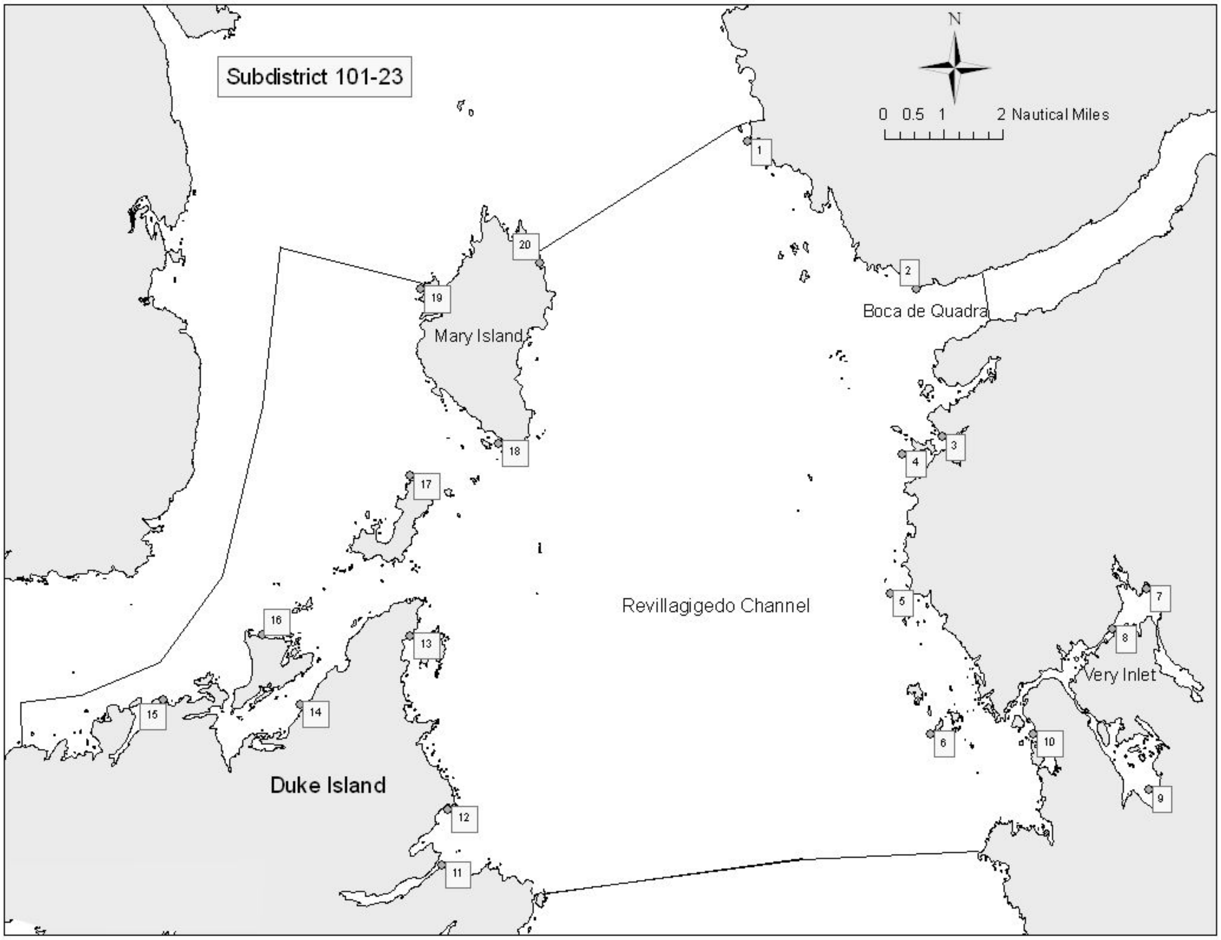
Appendix C1.–Location of transects surveyed in 2010 for commercial fishery Subdistricts 101-11-002.



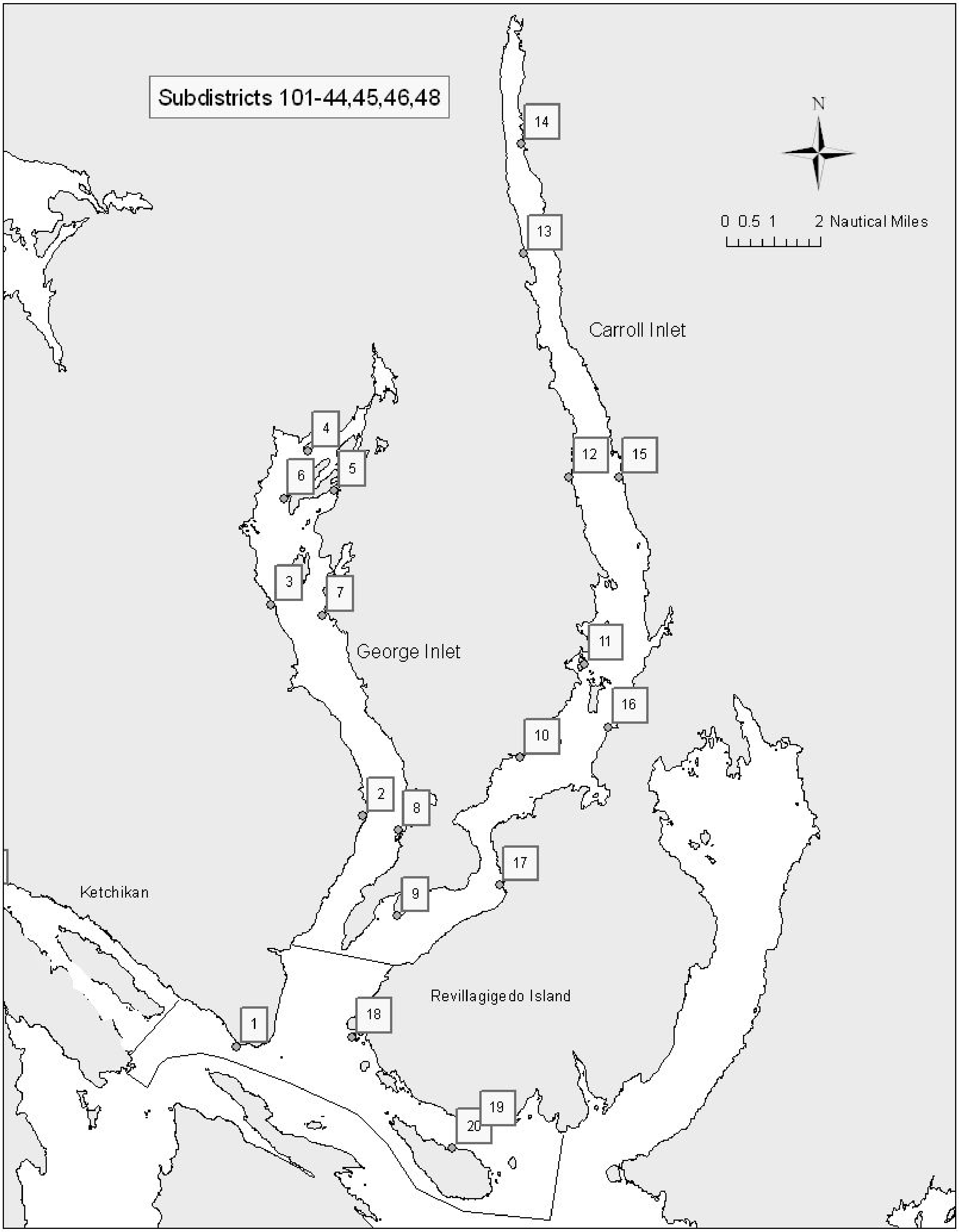
Appendix C2.–Location of transects surveyed in 2010 for commercial fishery Subdistrict 101-21. Black line indicates fishery area boundary.



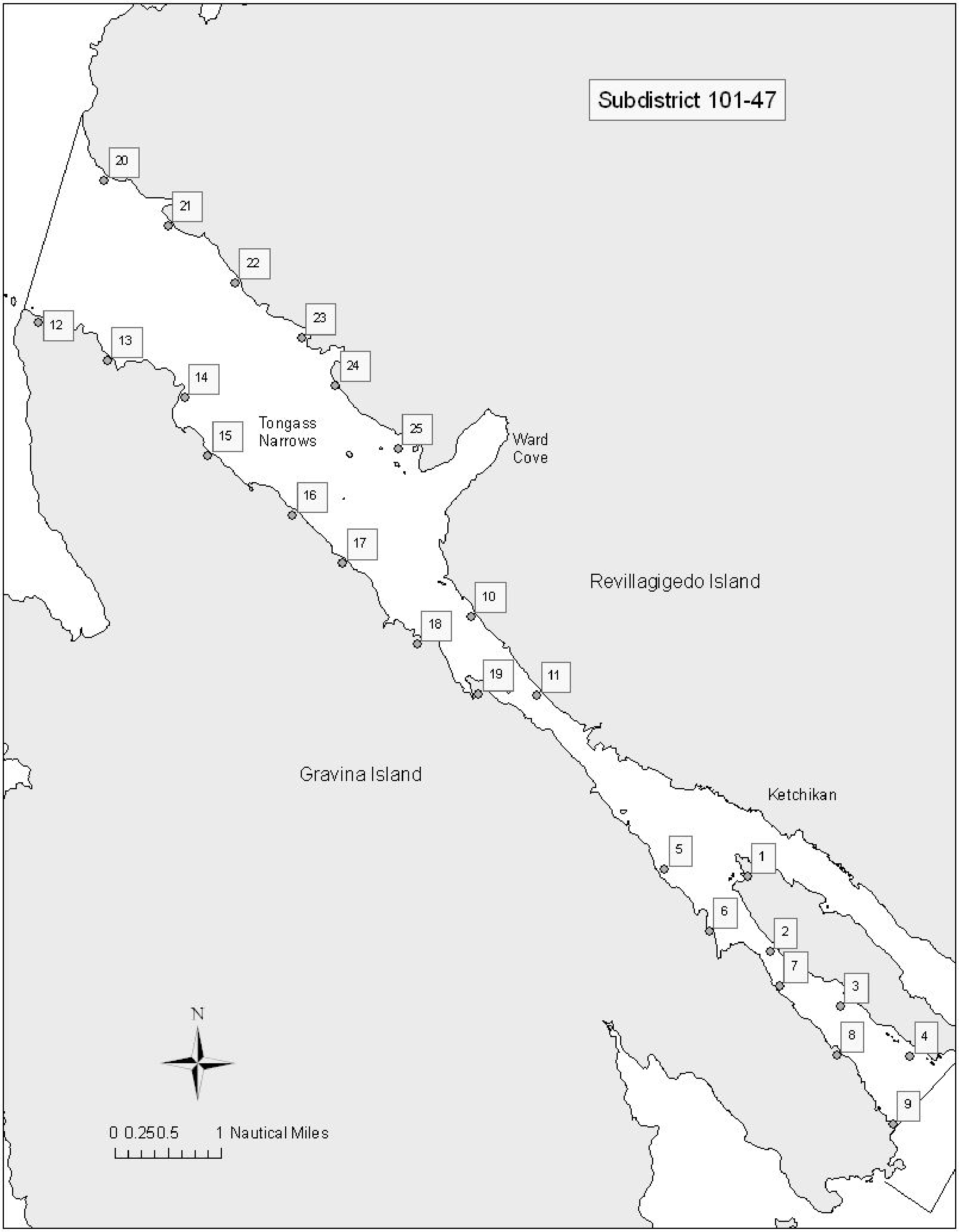
Appendix C3.–Location of transects surveyed in 2010 for commercial fishery Subdistricts 101-23. Black line indicates fishery area boundary.



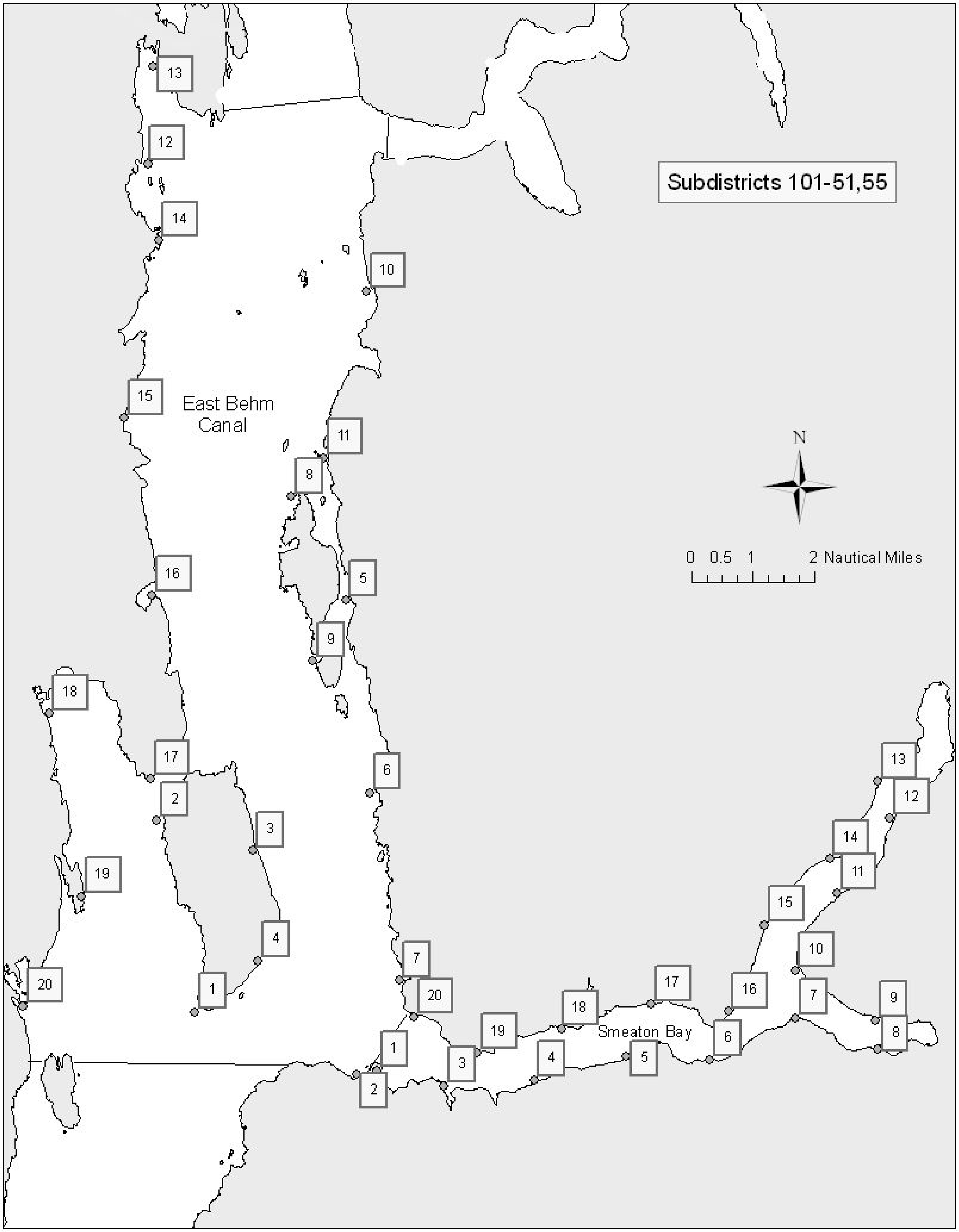
Appendix C4.–Location of transects surveyed in 2010 for commercial fishery Subdistrict 101-44,45,46,48. Black line indicates fishery area boundary.



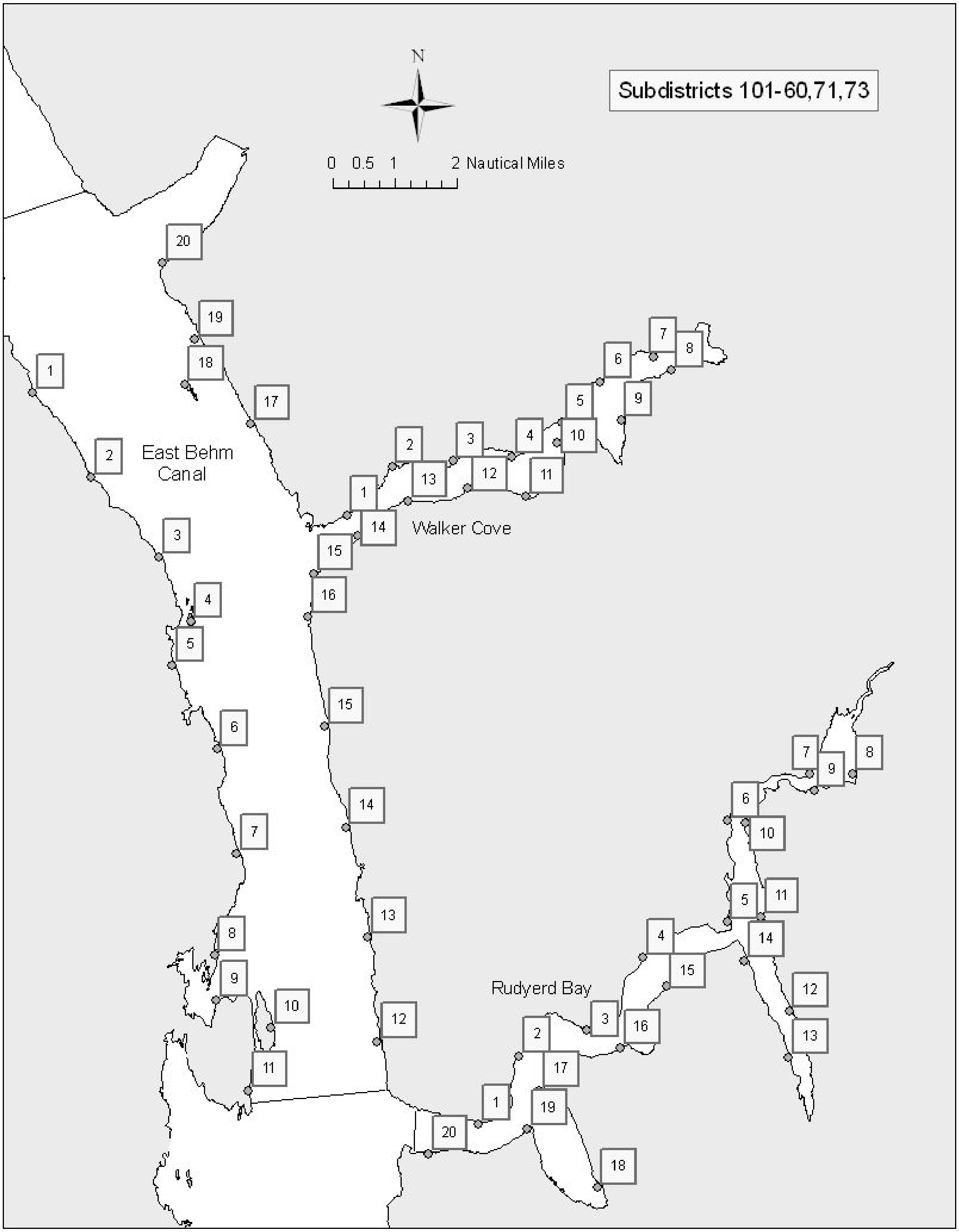
Appendix C5.–Location of transects surveyed in 2010 for commercial fishery Subdistrict 101-47. Black line indicates fishery area boundary.



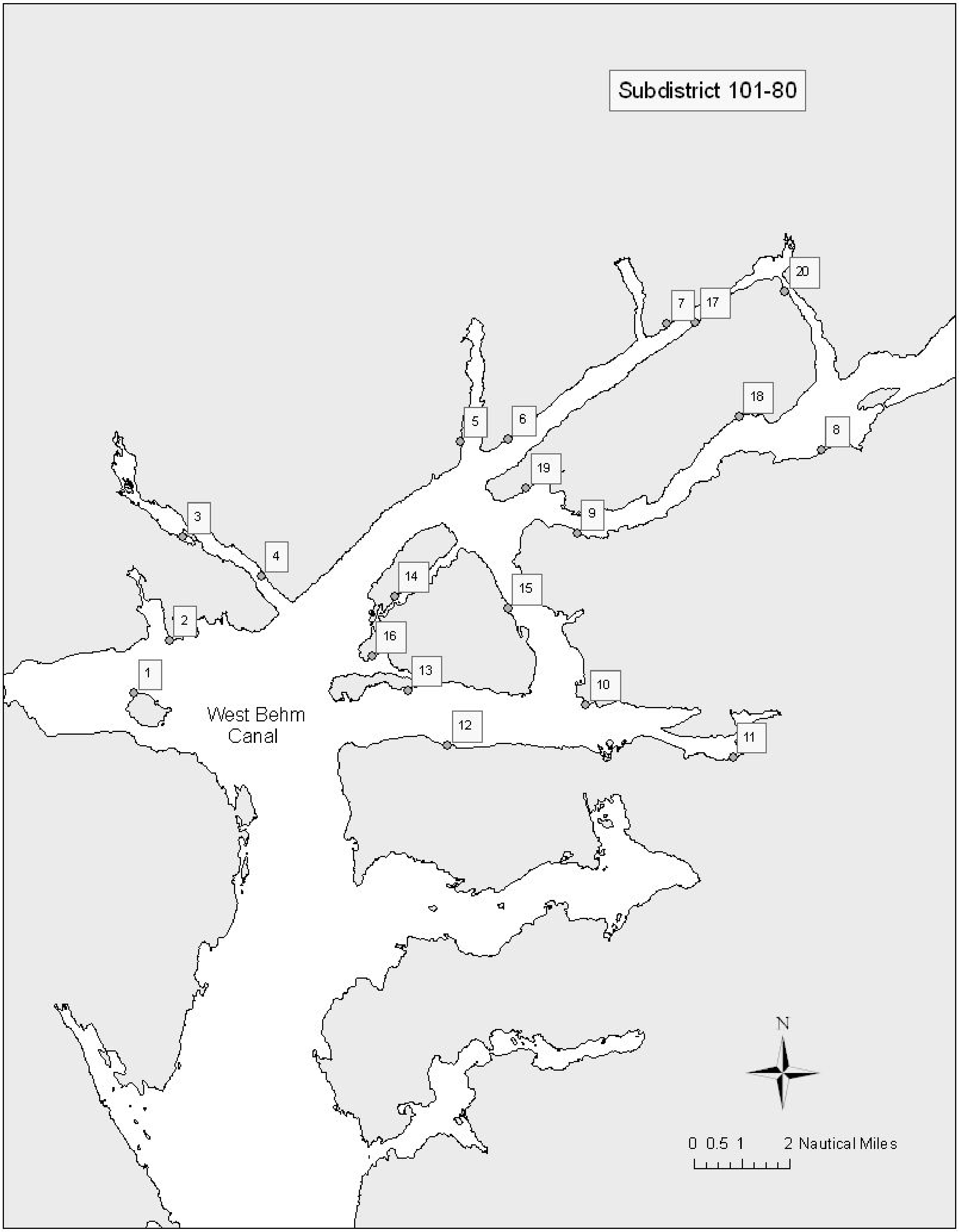
Appendix C6.–Location of transects surveyed in 2010 for commercial fishery Subdistrict 101-51,55. Black line indicates fishery area boundary.



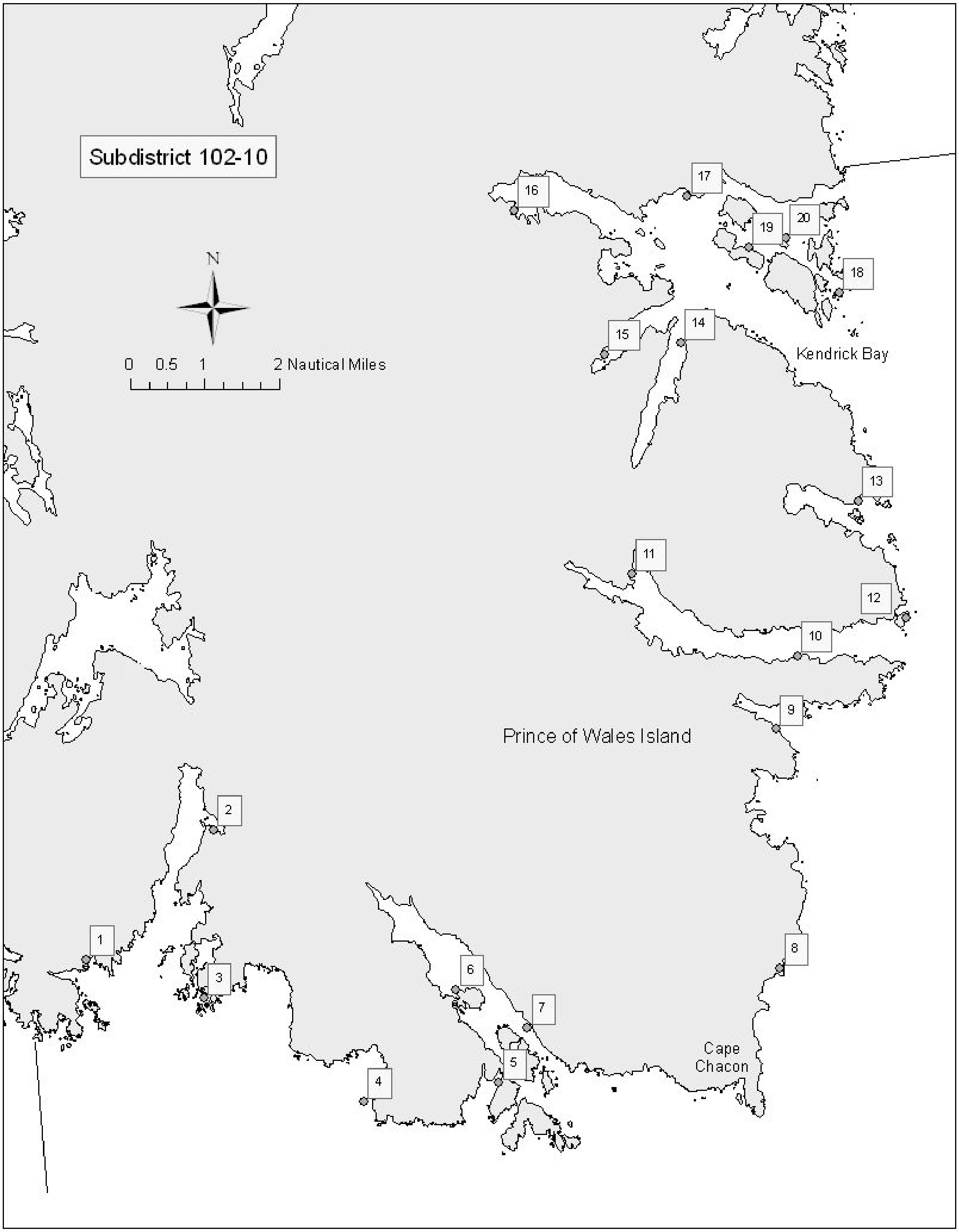
Appendix C7.–Location of transects surveyed in 2010 for commercial fishery Subdistricts 101-60,71,73. Black line indicates fishery area boundary.



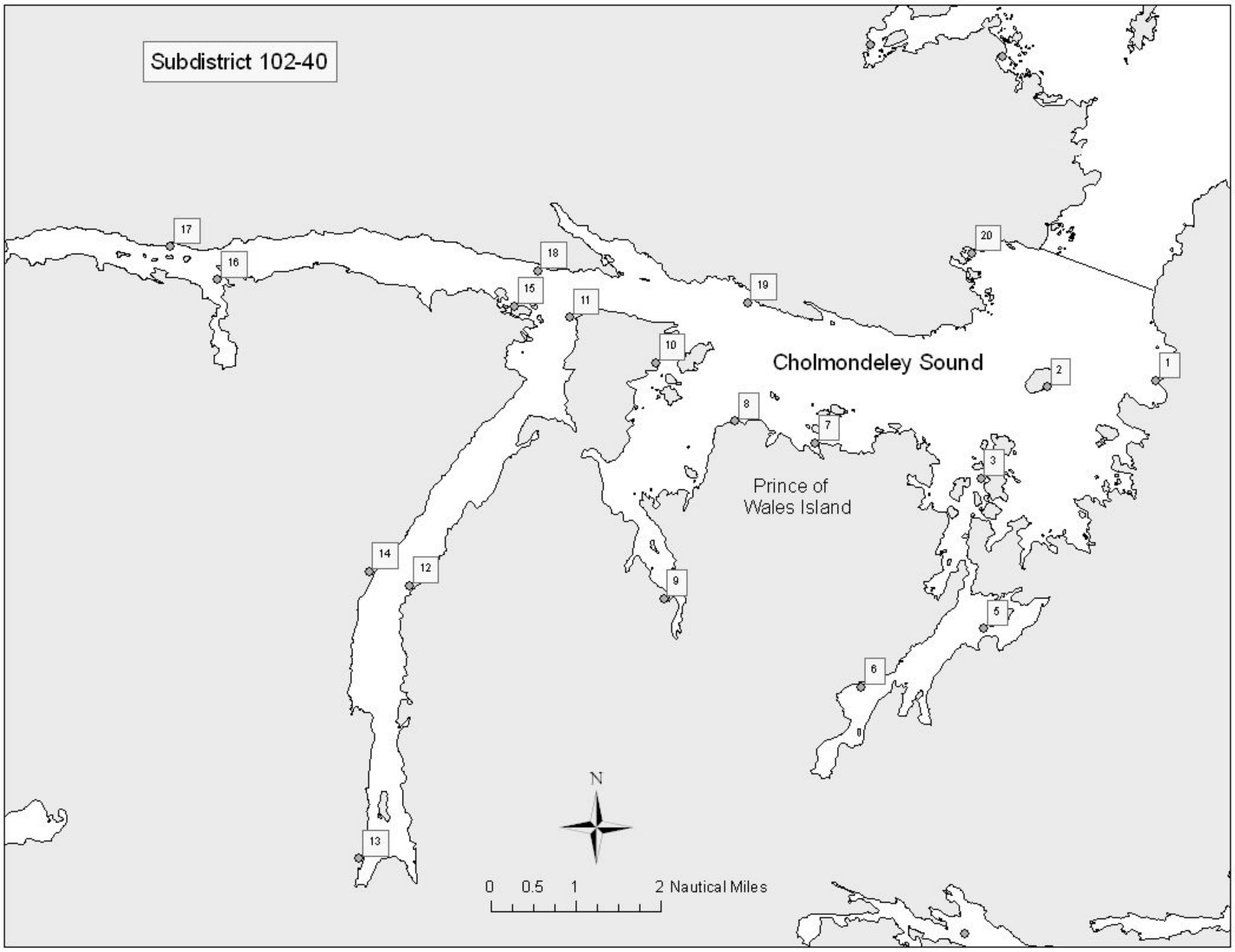
Appendix C8.–Location of transects surveyed in 2010 for commercial fishery Subdistricts 101-80. Black line indicates fishery area boundary.



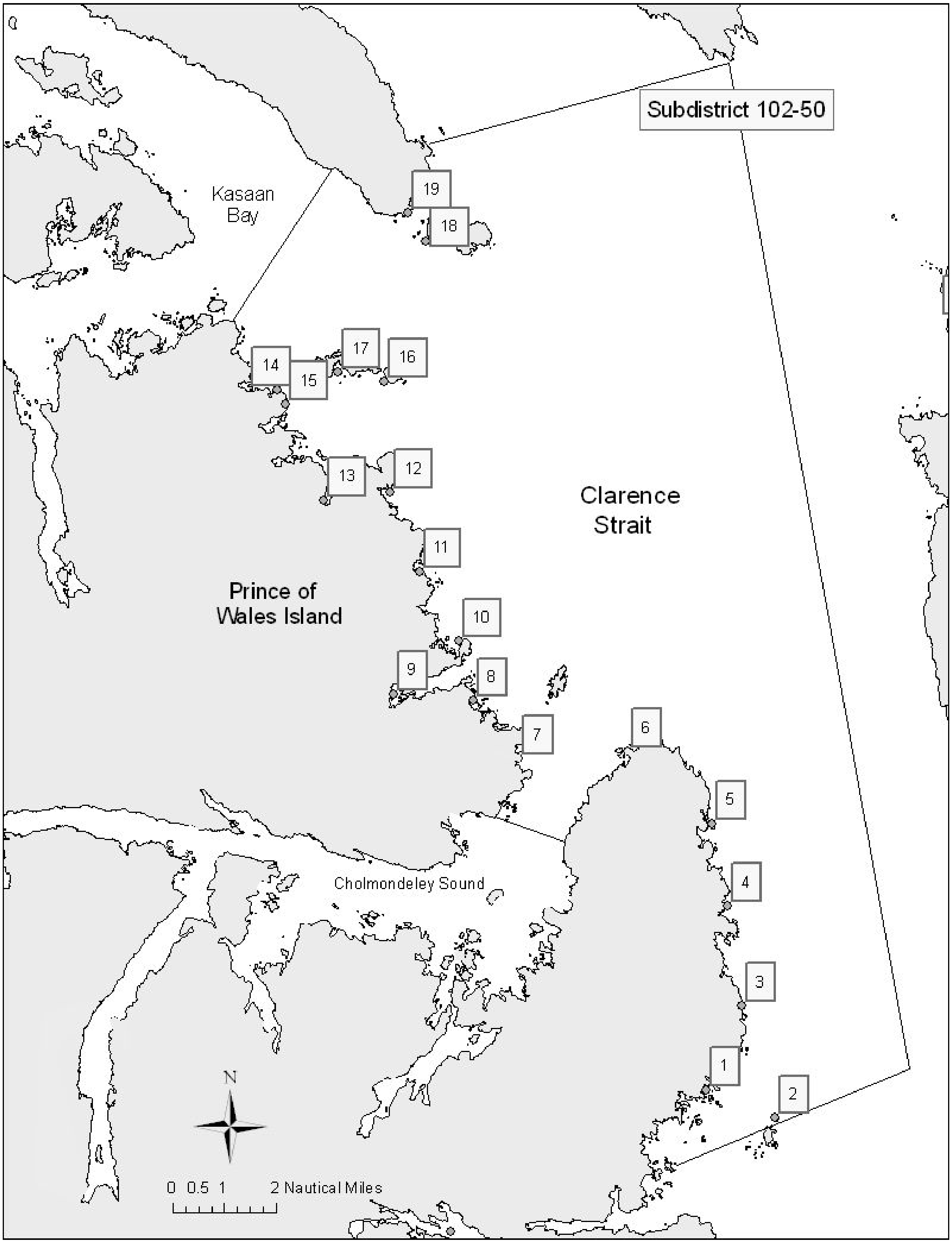
Appendix C9.–Location of transects surveyed in 2010 for commercial fishery Subdistricts 102-10. Black line indicates fishery area boundary.



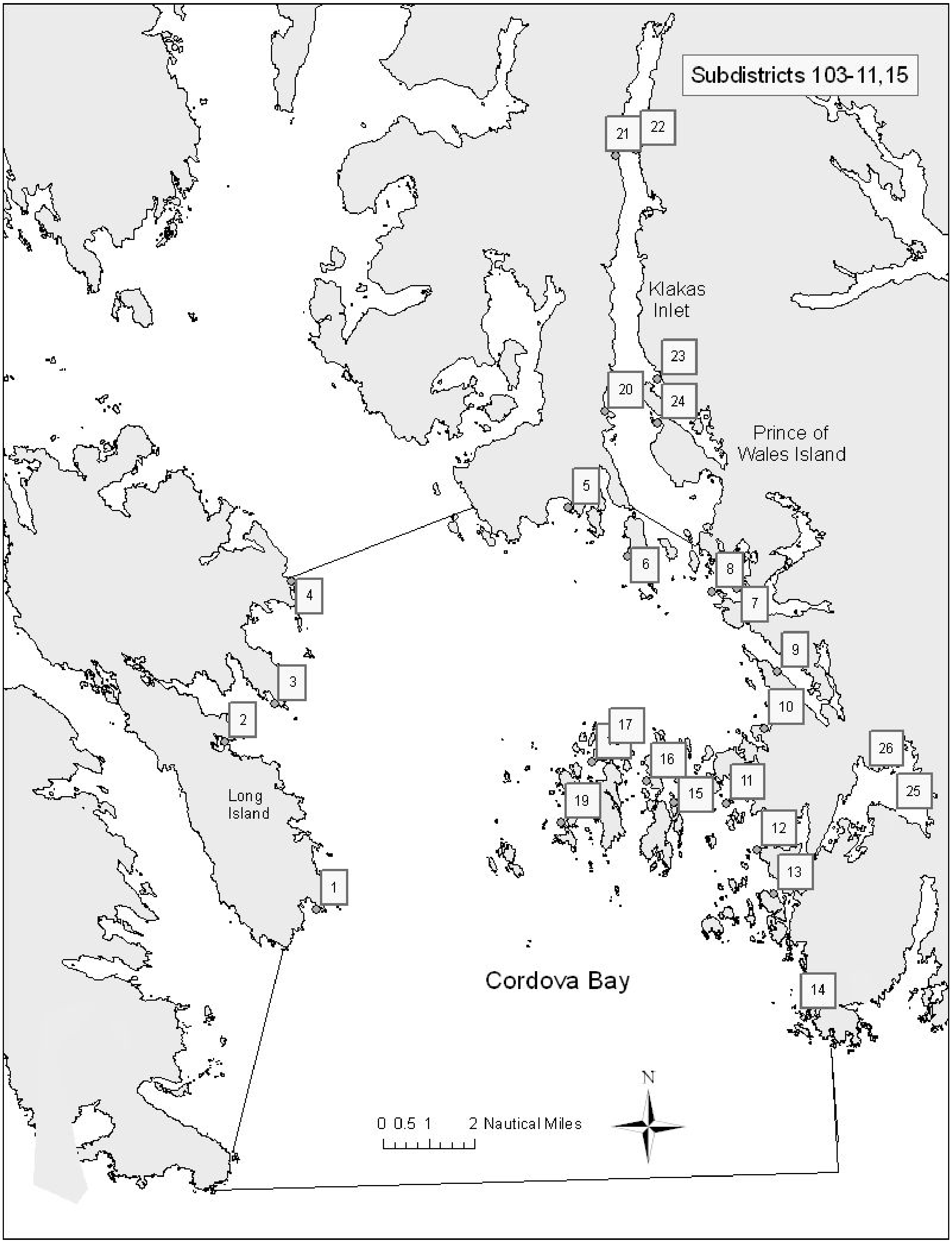
Appendix C10.–Location of transects surveyed in 2010 for commercial fishery Subdistrict 102-40. Black line indicates fishery area boundary.



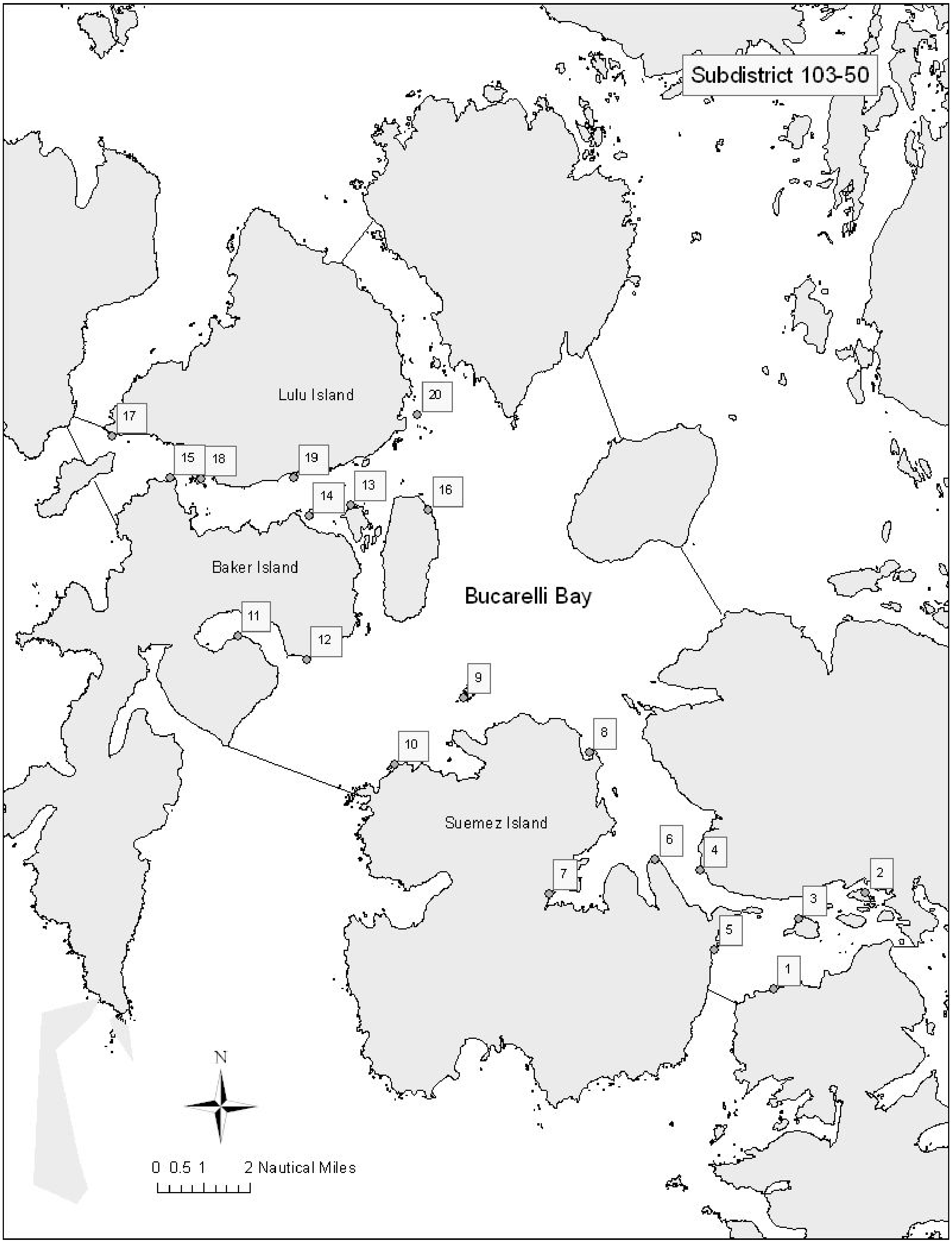
Appendix C11.–Location of transects surveyed in 2010 for commercial fishery Subdistrict 102-50. Black line indicates fishery area boundary.



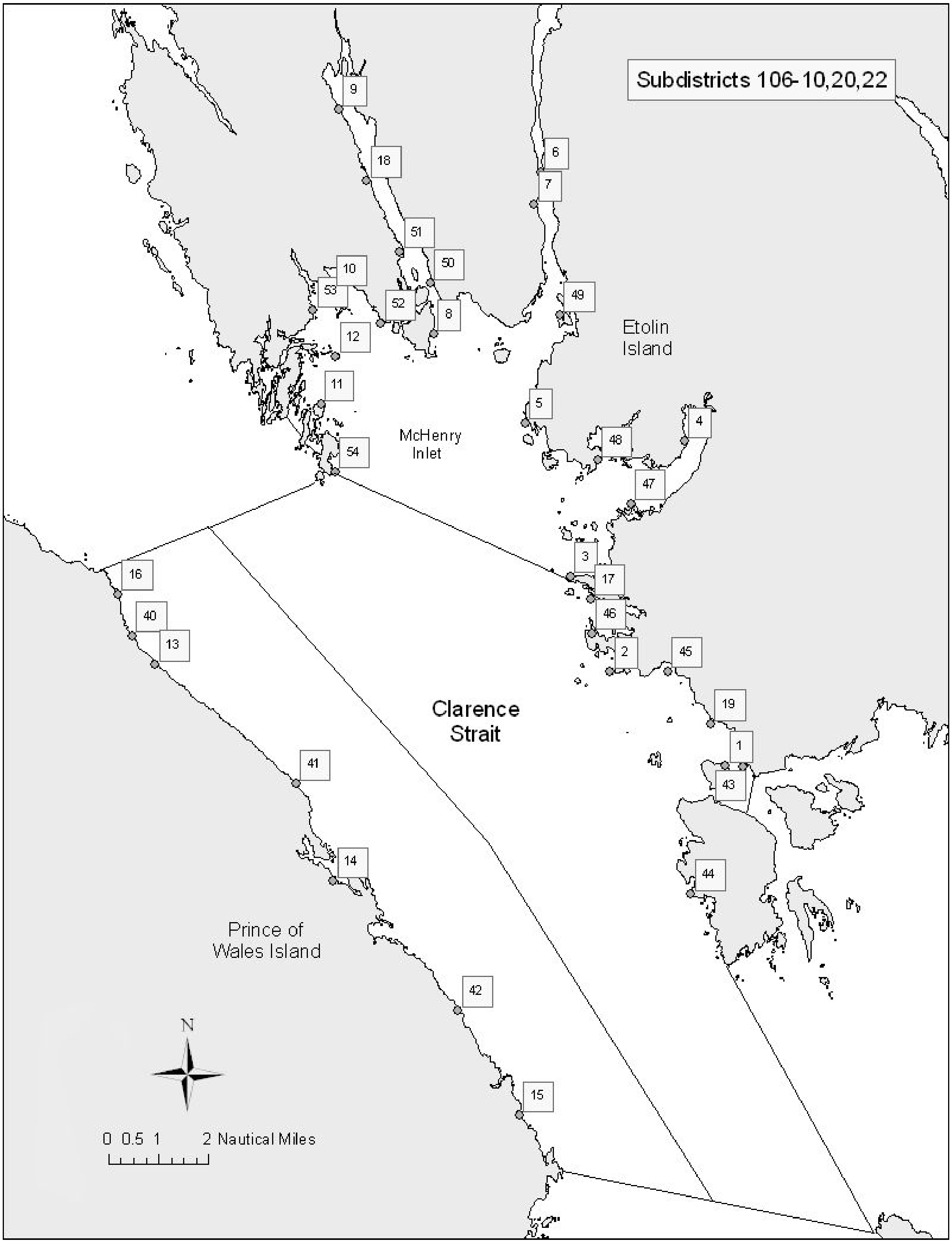
Appendix C12.–Location of transects surveyed in 2010 for commercial fishery Subdistricts 103-11,15. Black line indicates fishery area boundary.



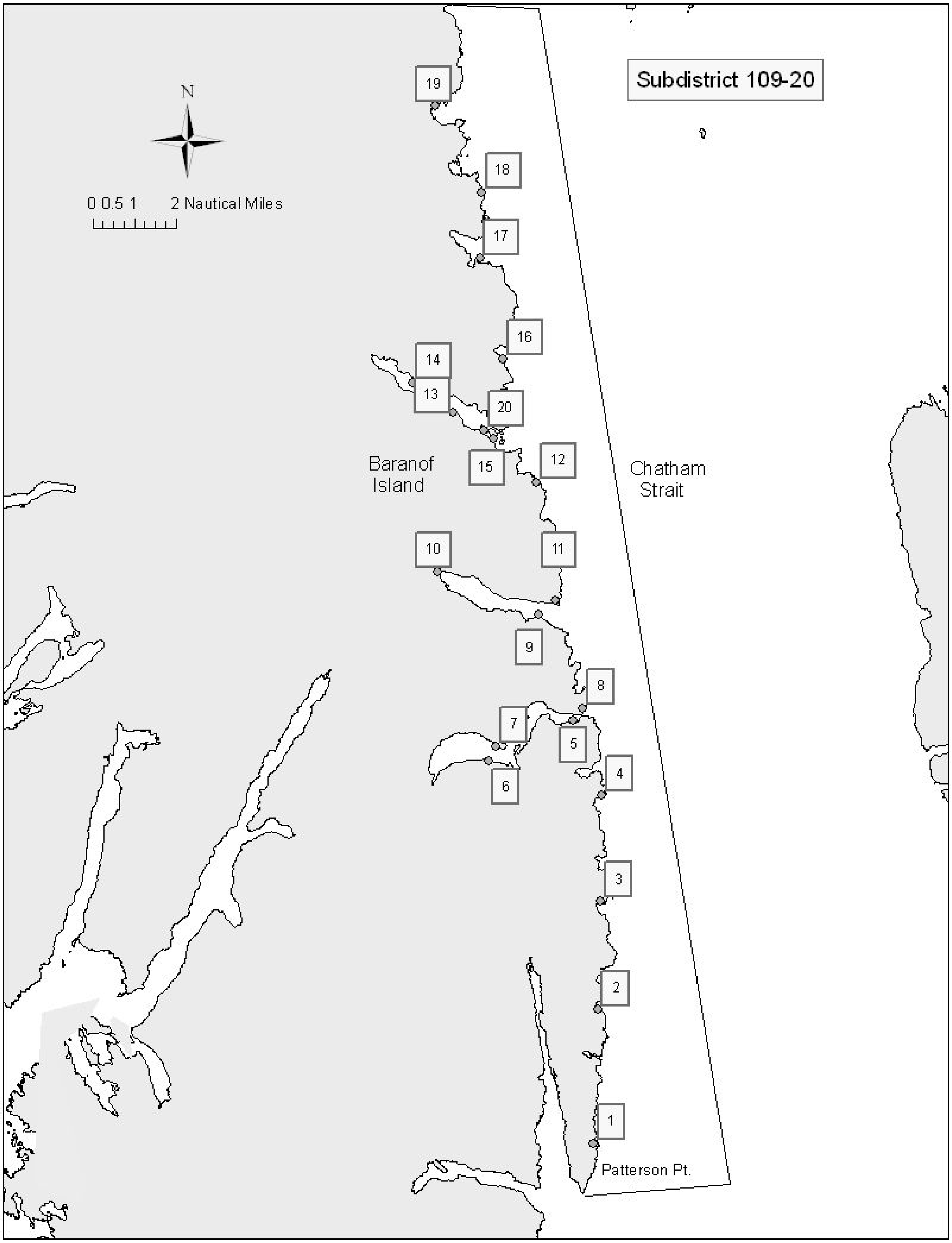
Appendix C13.–Location of transects surveyed in 2010 for commercial fishery Subdistrict 103-50. Black line indicates fishery area boundary.



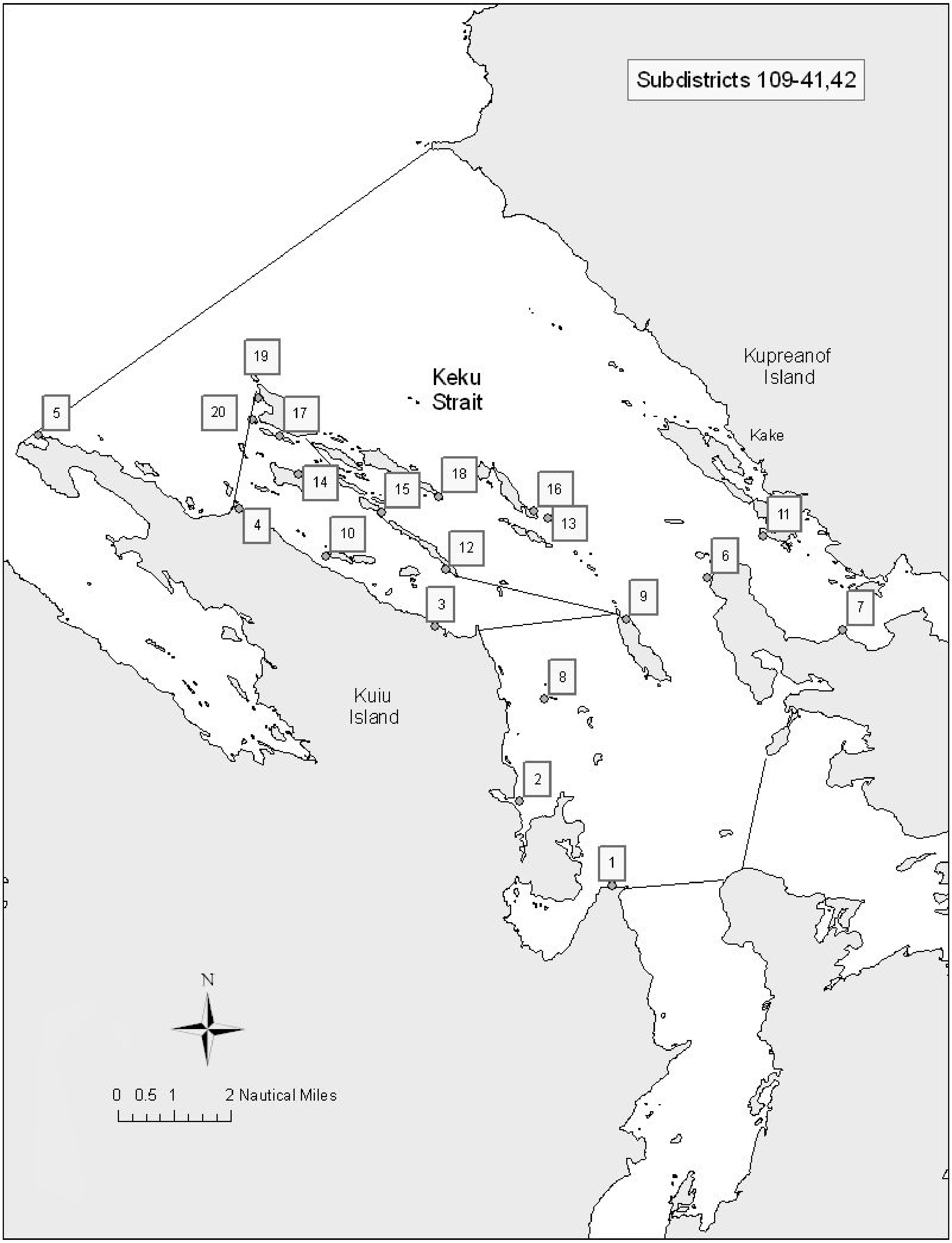
Appendix C14.–Location of transects surveyed in 2010 for commercial fishery Subdistricts 106-10,20,22. Black line indicates fishery area boundary.



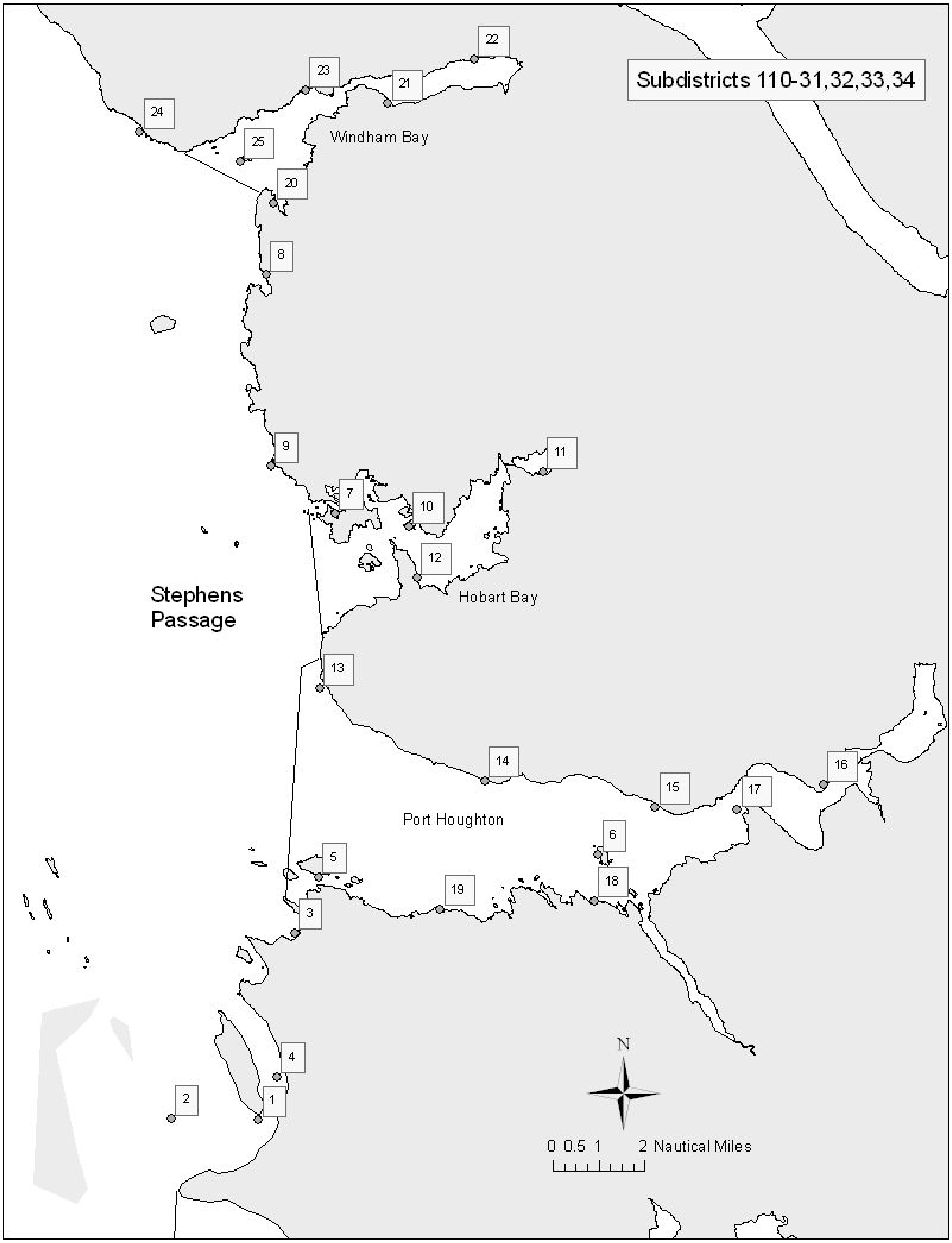
Appendix C15.–Location of transects surveyed in 2010 for commercial fishery Subdistrict 109-20. Black line indicates fishery area boundary.



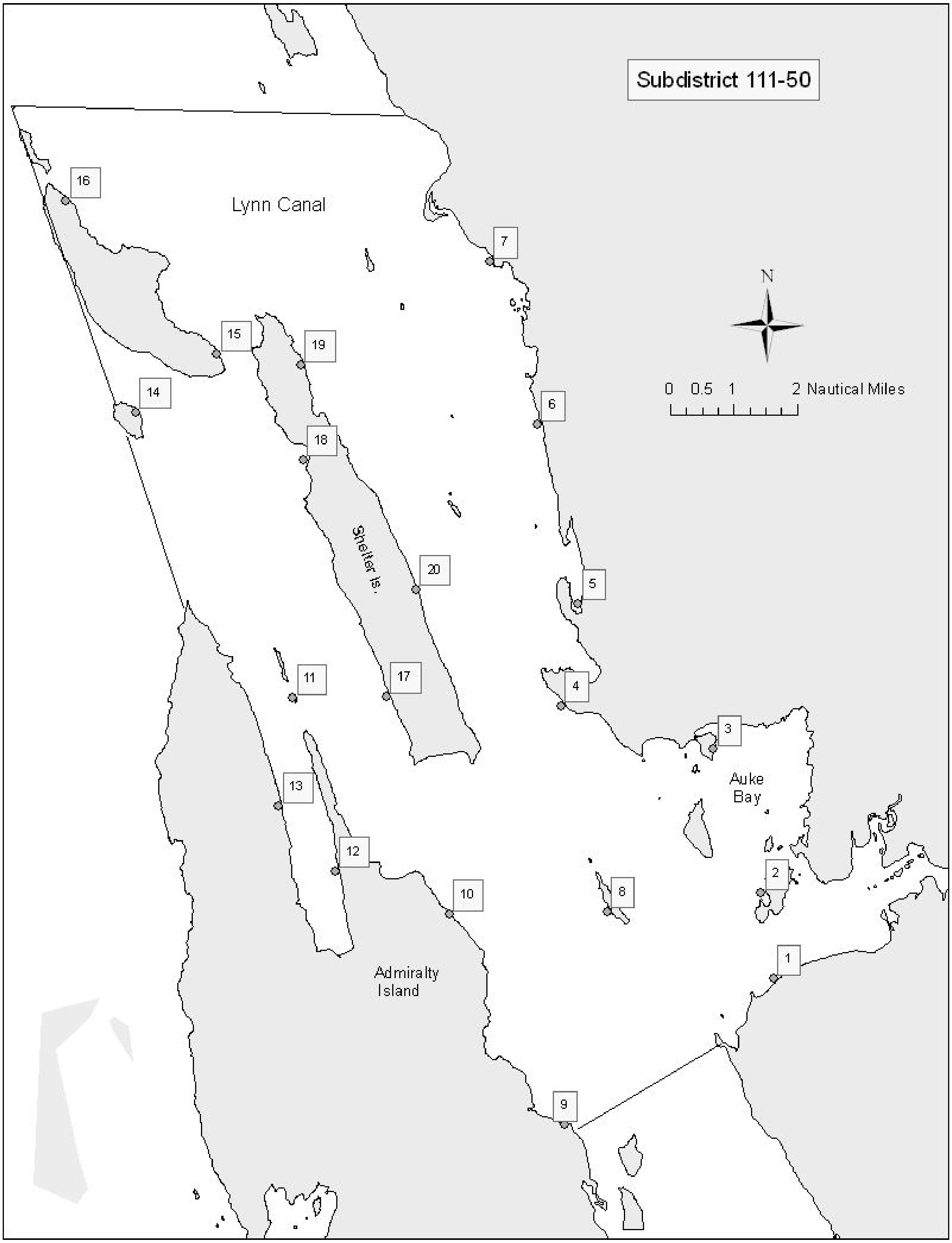
Appendix C16.–Location of transects surveyed in 2010 for commercial fishery Subdistricts 109-41,42. Black line indicates fishery area boundary.



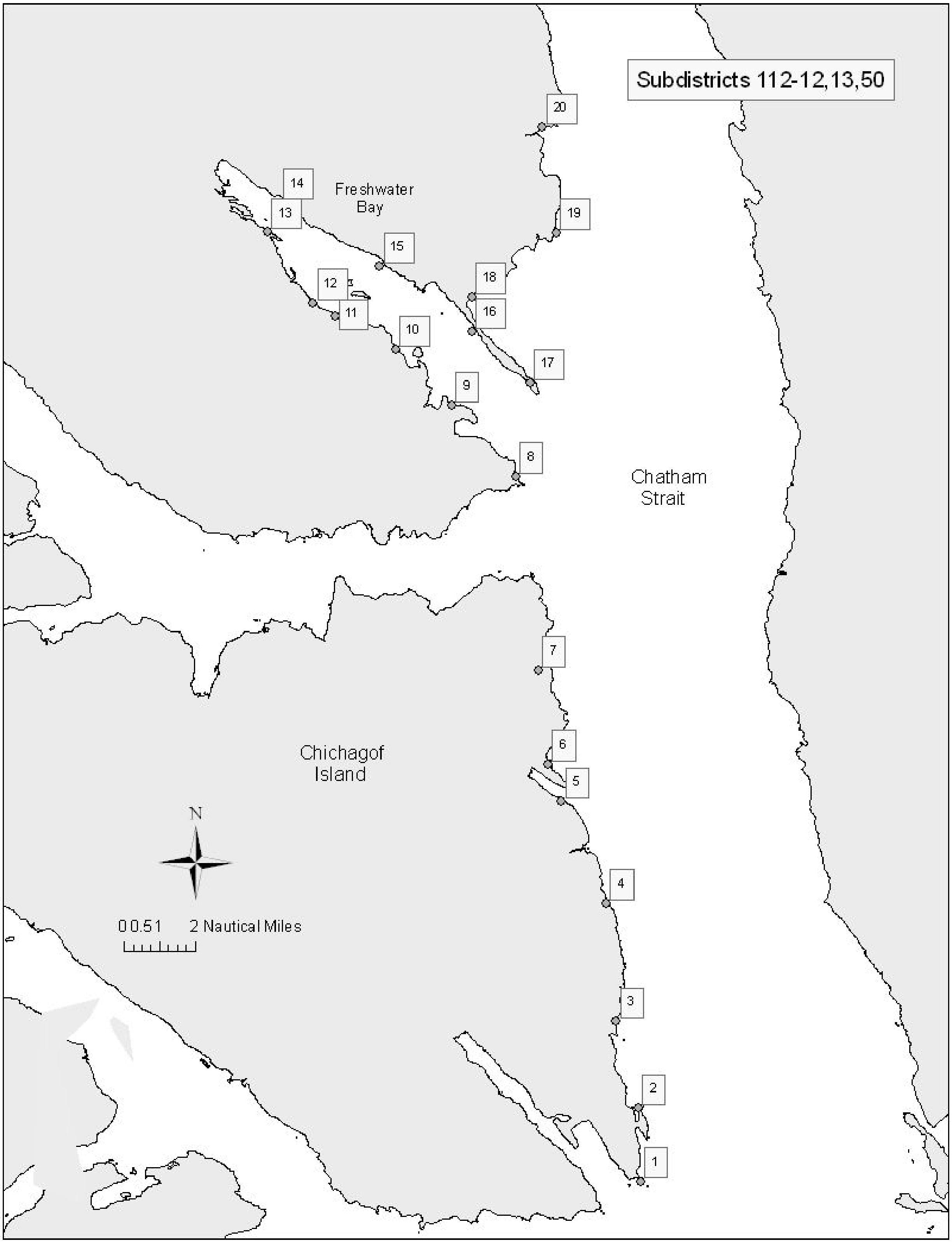
Appendix C17.–Location of transects surveyed in 2010 for commercial fishery Subdistricts 110-31,32,33,34. Black line indicates fishery area boundary.



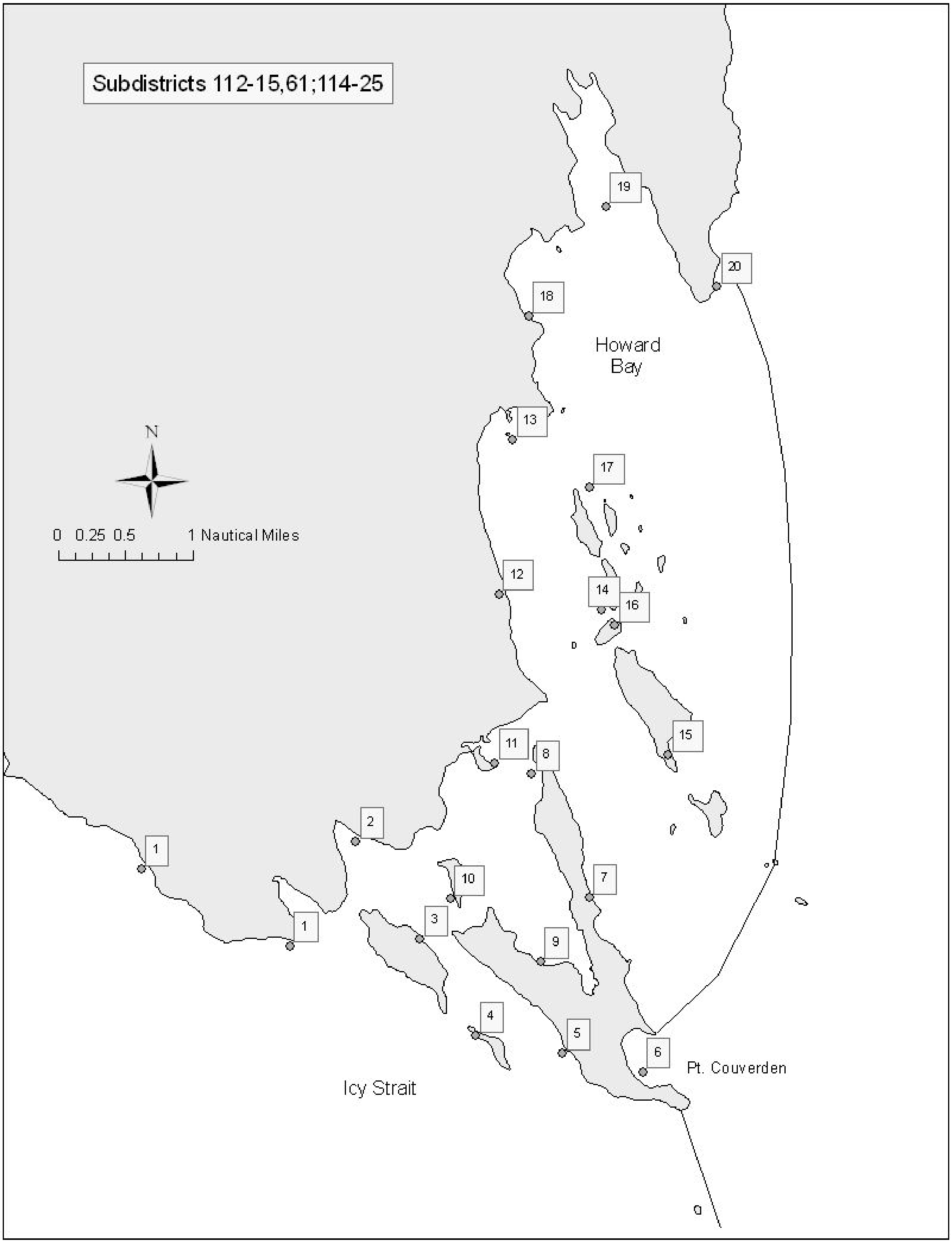
Appendix C18.–Location of transects surveyed in 2010 for commercial fishery Subdistricts 111-50. Black line indicates fishery area boundary.



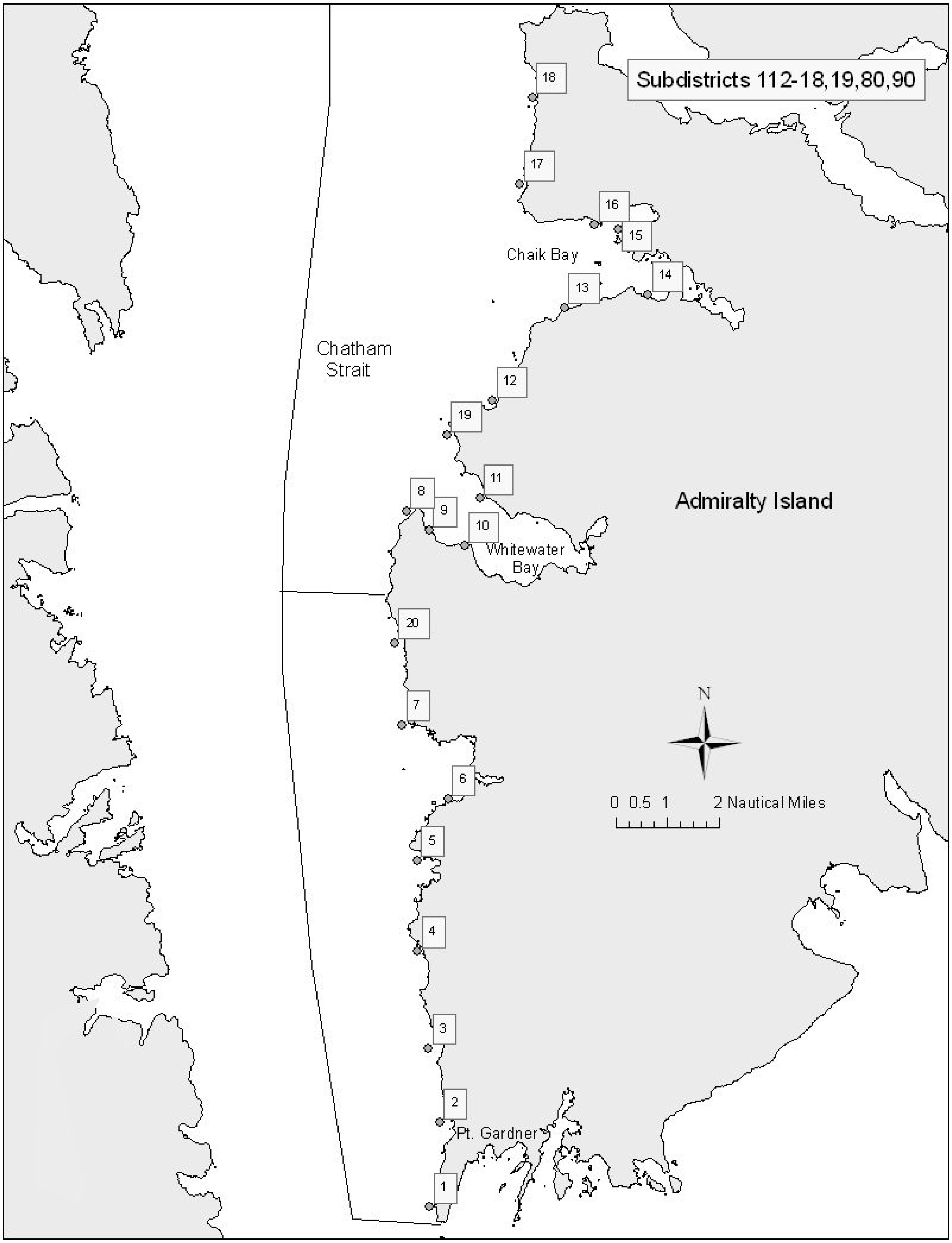
Appendix C19.–Location of transects surveyed in 2010 for commercial fishery Subdistricts 112-12,13,50. Black line indicates fishery area boundary.



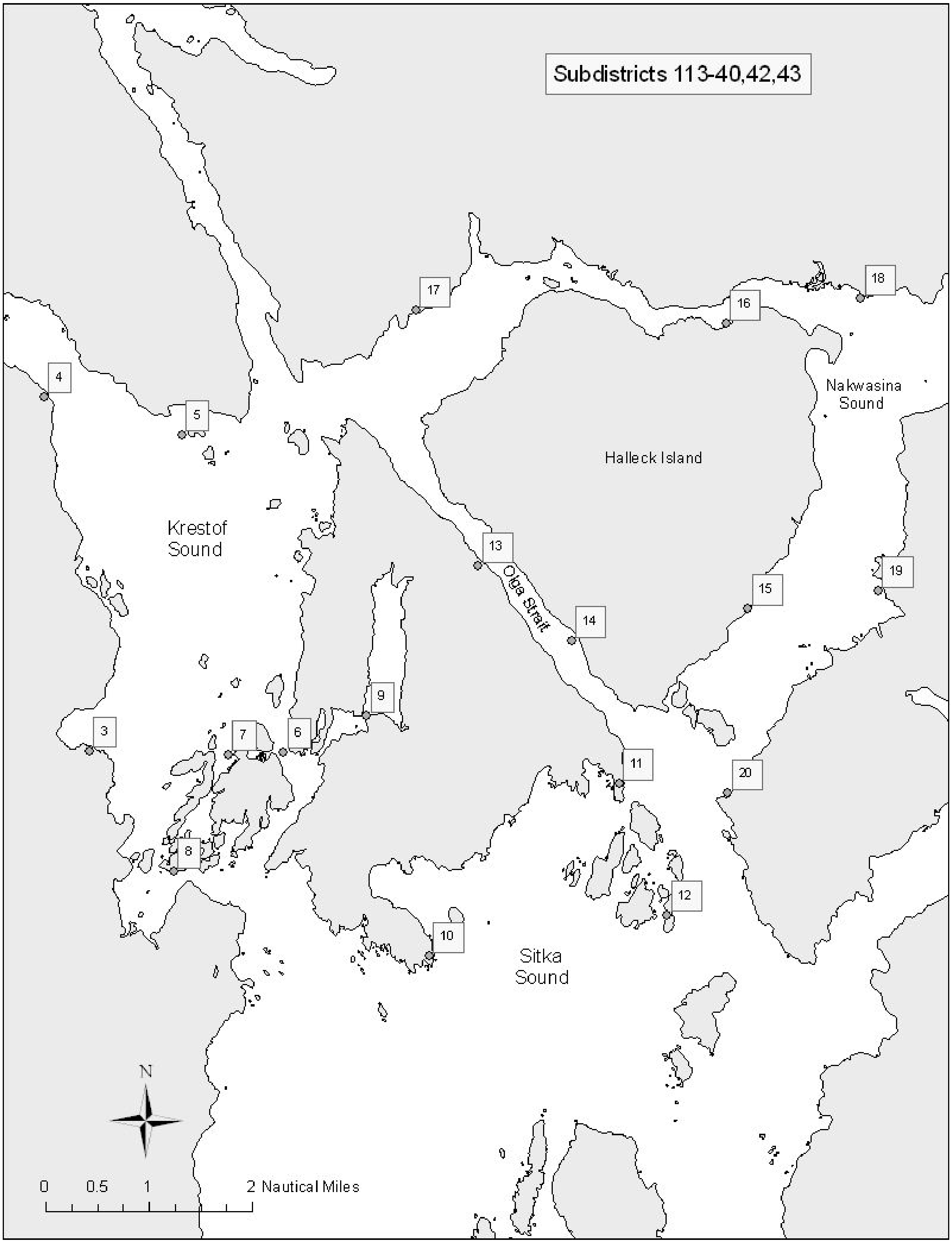
Appendix C20.–Location of transects surveyed in 2010 for commercial fishery Subdistricts 112-15,61,114-25. Black line indicates fishery area boundary.



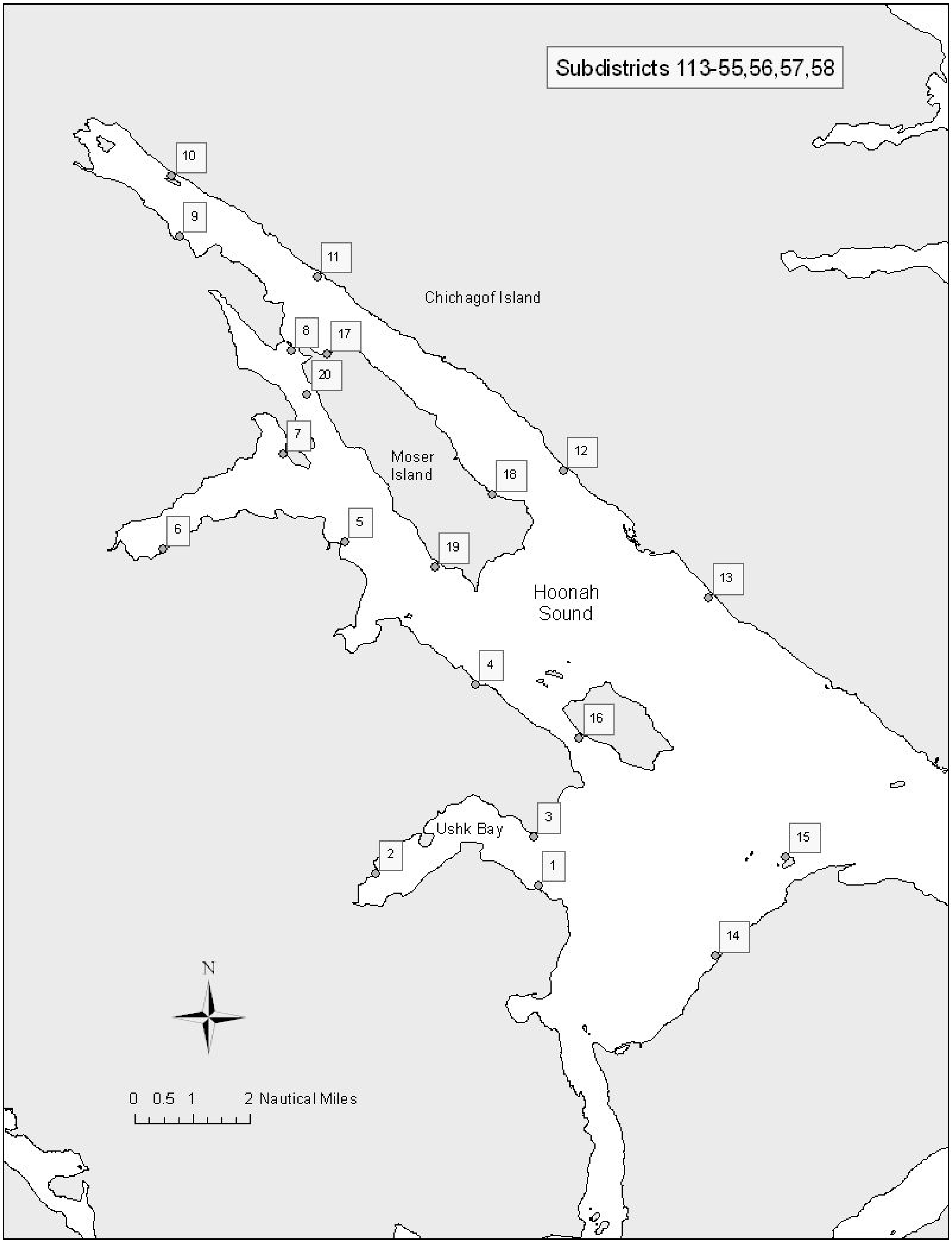
Appendix C21.–Location of transects surveyed in 2010 for commercial fishery Subdistricts 112-18,19,80,90. Black line indicates fishery area boundary.



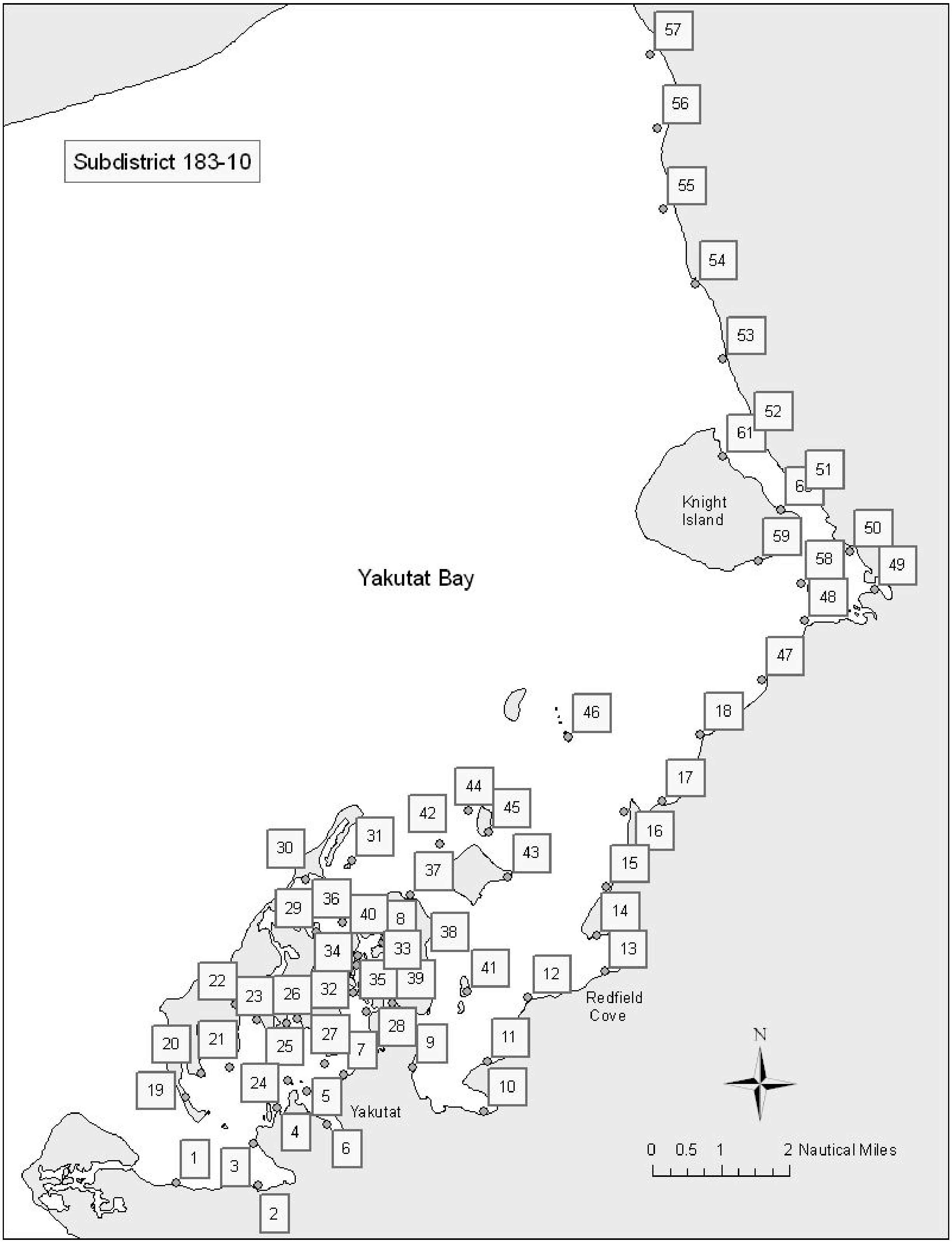
Appendix C22.–Location of transects surveyed in 2010 for commercial fishery Subdistricts 113-40,42,43. Black line indicates fishery area boundary.



Appendix C23.–Location of transects surveyed in 2010 for commercial fishery Subdistricts 113-55,56,57,58. Black line indicates fishery area boundary.

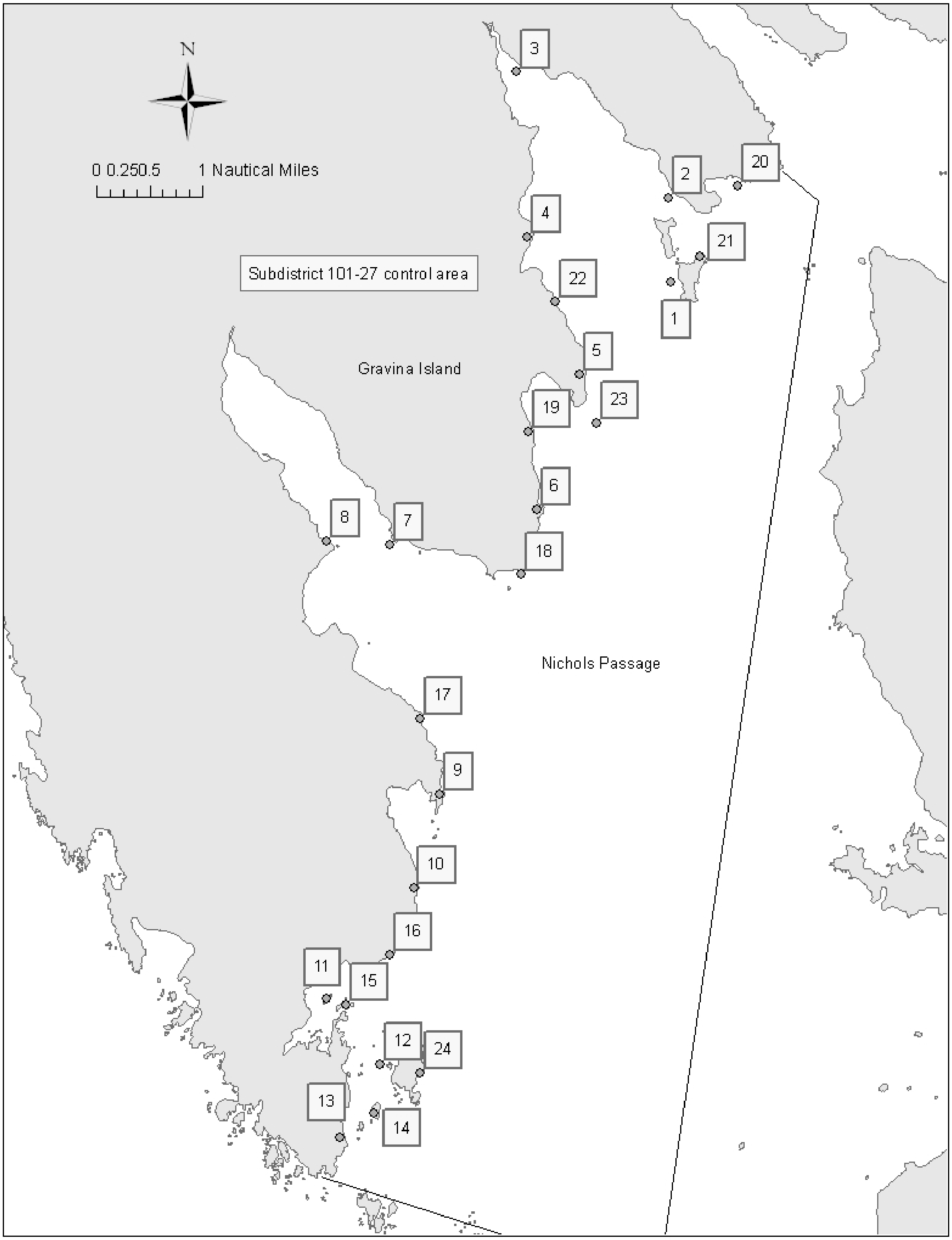


Appendix C24.–Location of transects surveyed in 2010 for commercial fishery Subdistrict 183-10. Black line indicates fishery area boundary.

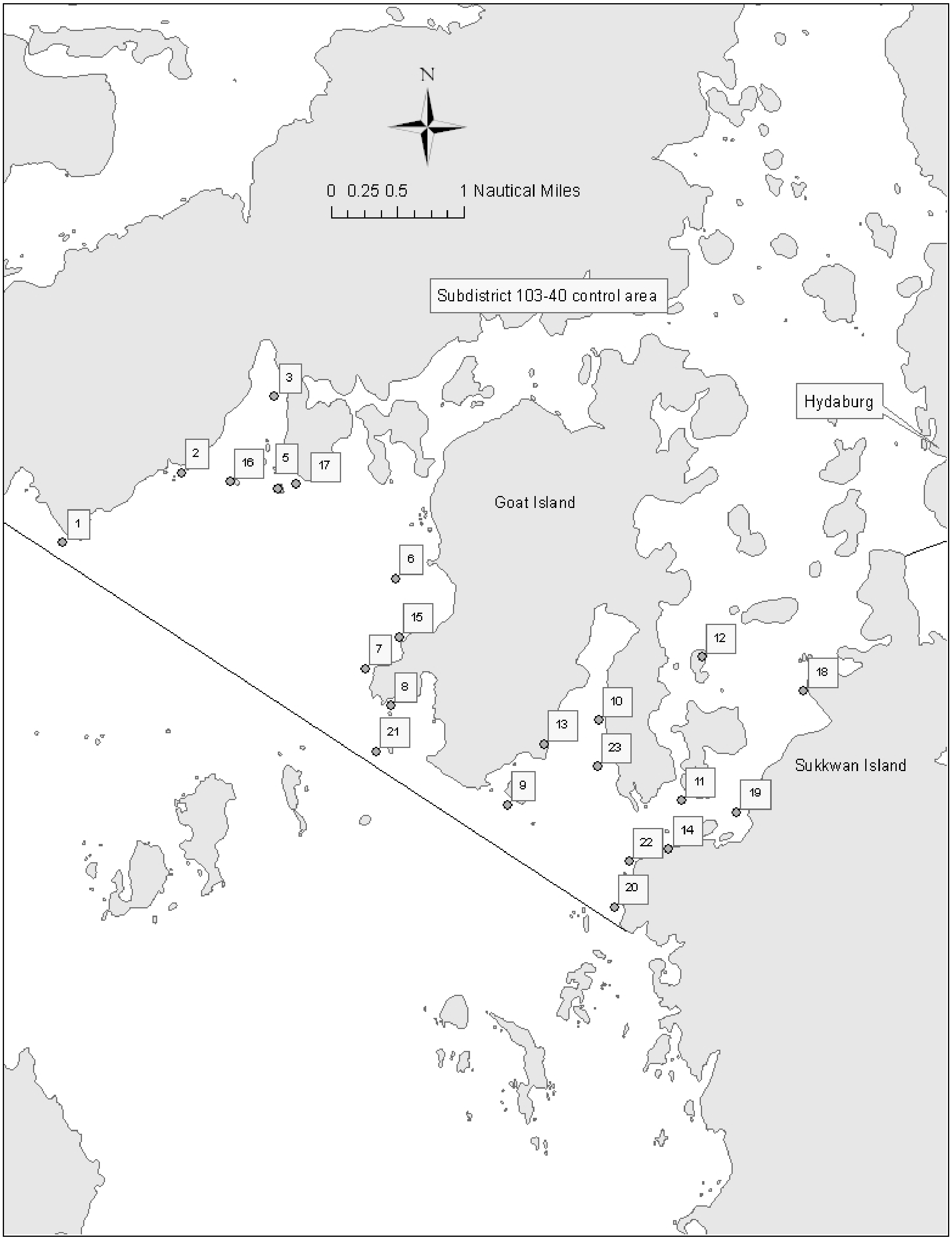


APPENDIX D: MAPS DISPLAYING CONTROL AREAS AND LOCATIONS OF TRANSECTS SURVEYED IN 2009

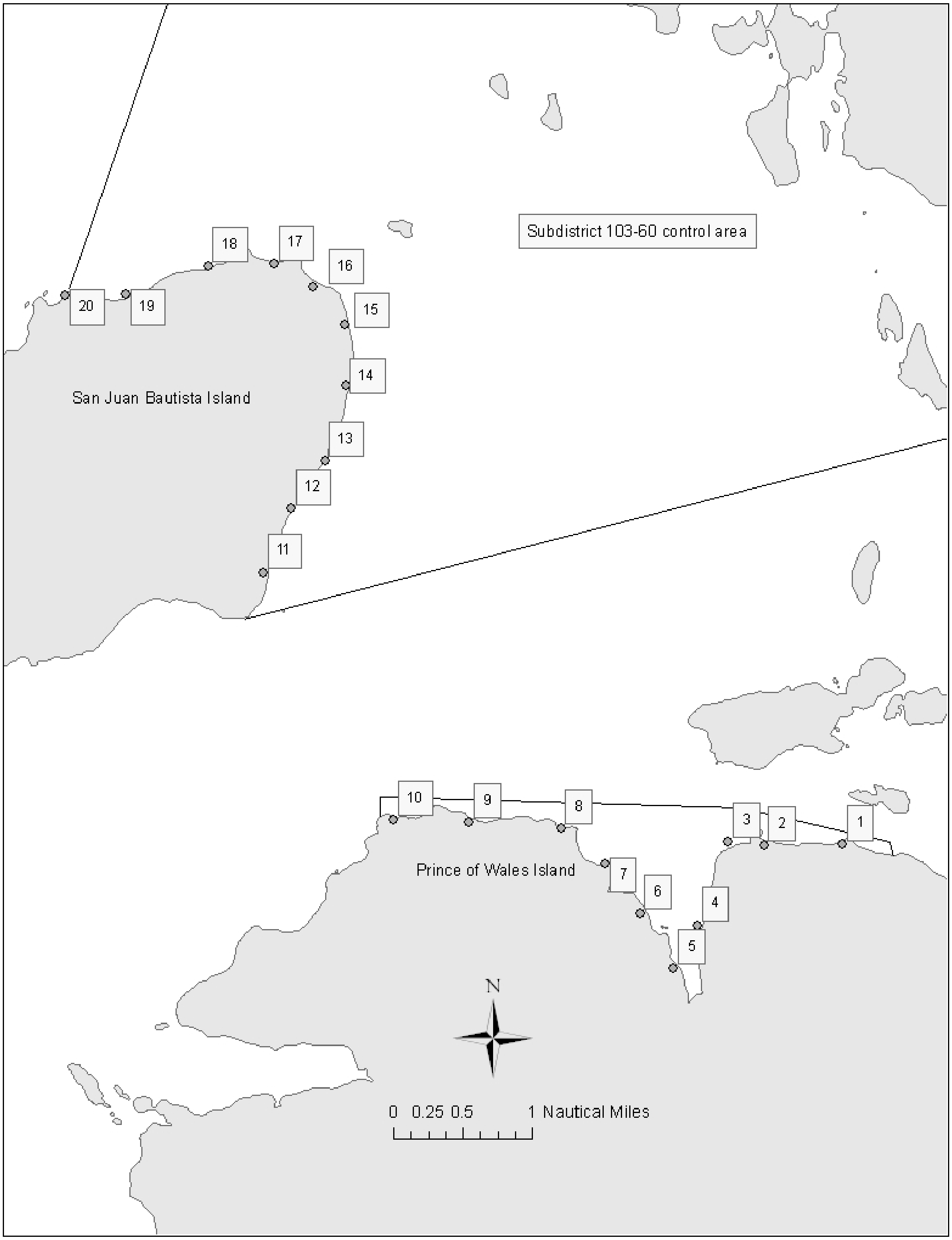
Appendix D1.–Location of transects surveyed in 2010 for control area Subdistrict 101-27. Black line indicates survey area boundary.



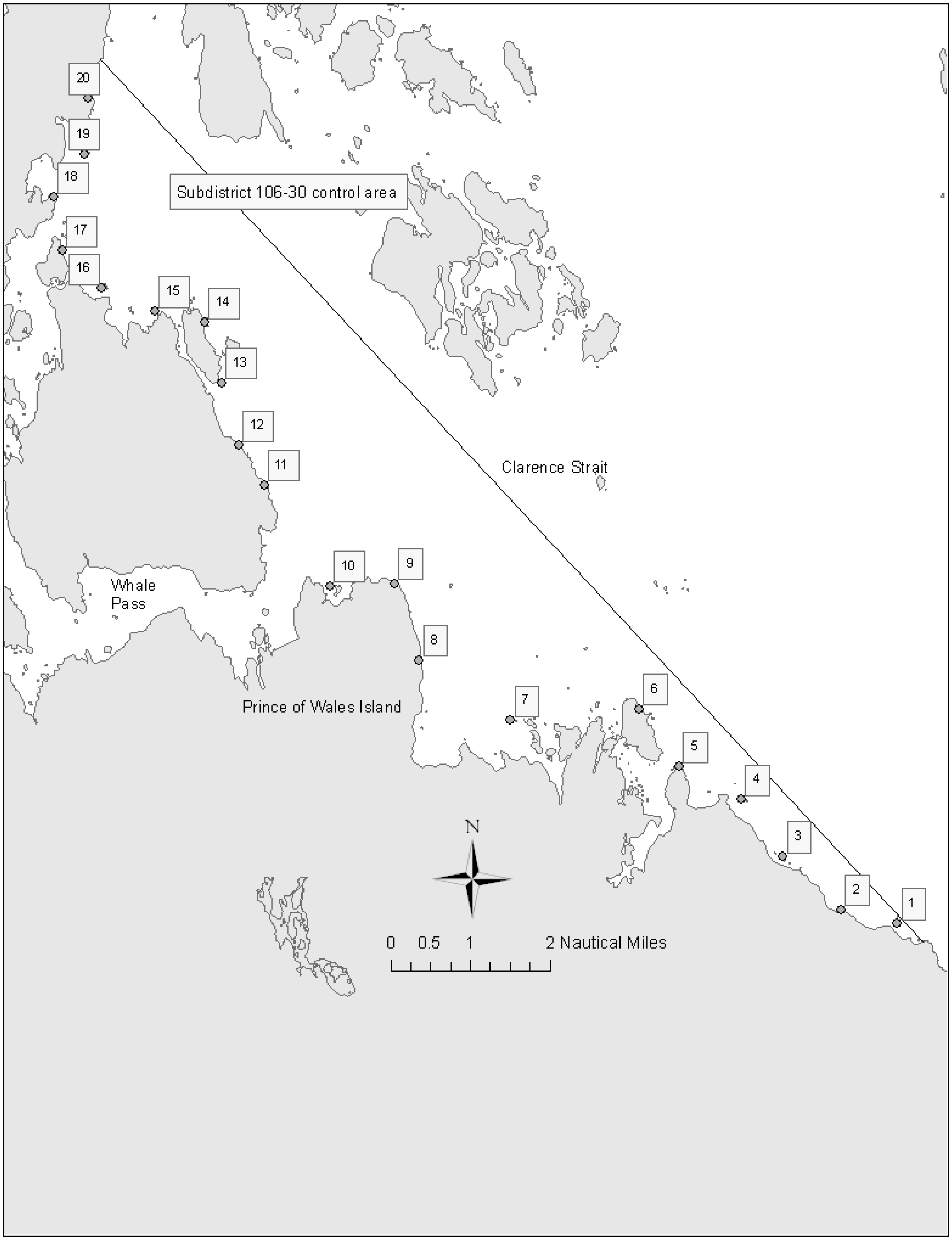
Appendix D2.–Location of transects surveyed in 2010 for control area Subdistrict 103-40. Black line indicates survey area boundary.



Appendix D3.–Location of transects surveyed in 2010 for control area Subdistrict 103-60. Black line indicates survey area boundary.



Appendix D4.–Location of transects surveyed in 2010 for control area Subdistrict 106-30. Black line indicates survey area boundary.



Appendix D5.–Location of transects surveyed in 2010 for control area Subdistrict 113-40. Black line indicates survey area boundary.