Fishery Data Series No. 12-26

Southeast Alaska Sea Cucumber Stock Assessment Surveys in 2011

by

Kyle Hebert

July 2012

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)

Measures (fisheries)

fork length	FL
mideye to fork	MEF
mideye to tail fork	METF
standard length	SL
total length	TL

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 SERIES NO. 12-26

SOUTHEAST ALASKA SEA CUCUMBER STOCK ASSESSMENT SURVEYS IN 2011

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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 2011 survey season, a total of 440 transects were completed during 20 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 8 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 2011, the highest biomass of sea cucumbers was found in Subdistrict 103-40-001,002,004, at 1,032,330 pounds (468,678 kg), and the lowest biomass was found in Subdistricts 113-38, 41 at 110,535 pounds (50,183 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 2011 survey season, and additionally includes result from surveys conducted in 1990, 1993, 1996, 1999, 2002, 2005, and 2008 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 1990/2011 rotation). Surveys conducted during 2011 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 SURVEY

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 2011 comprise one of three fishing area rotational groups. Population assessment surveys were conducted in many of the same fishing areas as in 1990, 1993, 1996, 1999, 2002, 2005, and 2008. 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 2011. 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 2011 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).

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

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 2011 are presented in Appendix C (commercial areas) and Appendix D (control areas).

Transect locations are fixed and are resurveyed with each triennial survey. 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 2011, 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:

$$d = \sum_{i=1}^{n} \frac{C_i}{4n} \qquad (1)$$

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,

$$\sigma^2_{N_C} = \sigma^2_d L^2 \quad . \tag{8}$$

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

The biomass (B_c) is estimated as,

$$B_C = N_C W_A \quad . \tag{9}$$

Biomass variance is estimated as,

$$\sigma^2_{B_C} = (\sigma^2_d W^2_A + \sigma^2_{W_A} d^2 - \sigma^2_d \sigma^2_{W_A}) L^2 \tag{10}$$

.

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 2011 the density of sea cucumbers in commercial fishery areas ranged from 20.3, in Subdistrict 107-10, to 1.5 in Subdistricts 103-90 and in Subdistricts 107-40,45 (Table 1; Figure 3). Density of sea cucumbers is variable among fishery areas and among years, and for most areas, there is no clear trend (Figures 4–13). Although there may be visual trends of point estimates for some areas, the confidence intervals often overlap from year-to-year, reducing the likelihood that trends are statistically significant. Areas where there exists visual indication of declining density include Subdistrict 101-29, Subdistricts 101-41,43,53, Subdistrict 103-40-001,002,004, Subdistrict 103-90, Subdistricts 104-10,20,30, Subdistricts 113-31,32,33, and Subdistricts 113-38,41. In some of these areas (103-40-001,002,004, 103-90, 104-10,20,30, 113-31,32,33, and 113-38,41), sea otters are present and are suspected to have contributed to declining sea cucumber density. 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 stable; however there appear to be no areas where density is increasing.

Average sea cucumber weight estimates in 2011 ranged from 134 grams in Subdistricts 101-44,45,46,48, to 256 grams in Subdistrict 103-40-001,002,004 (Table 2; Figure 14). Average weight appears to be stable over time for most areas, and possibly increasing in some areas (Figures 15–24). There are no areas in the 1990/2011 rotation where there is evidence of declining average weight.

The highest estimate of biomass in 2011 was in Subdistrict 103-40-001,002,004, at 1,032,330 pounds (468,678 kg) and the lowest was in Subdistricts 113-38,41, at 110,535 pounds (50,183 kg) (Table 3; Figure 25). Biomass estimates are the product of estimates of mean density and mean 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 26), except in areas where sea otters are present, which results in disproportionately low density. An example of this exception may be found in Subdistrict 103-90, where the shoreline length is the highest among areas in the 1990/2011 rotation; however, biomass estimates are about one-third that of the highest biomass estimate in the rotation.

Although tracking estimates of sea cucumber biomass over time may provide an indication of trends in overall population levels, conclusions must be made 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, 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 closely follow trends in sea cucumber density. The reason for this is that of the three factors used to calculate biomass (density, weight, shoreline length), weight and shoreline length are relatively stable or constant over time. Areas where there exists indications of declining biomass include Subdistrict 101-29, Subdistricts 101-41,43,53, Subdistrict 103-40-001,002,004, Subdistrict 103-90, Subdistricts 104-10,20,30, Subdistricts 113-31,32,33, and Subdistricts 113-38,41. Sea otter predation is suspected at least in part for the declines apparent in Districts 3, 4 and 13. There appear to be no areas in this rotation with an increasing trend for biomass. The trends observed in the 1990/2011 rotation for sea cucumber biomass, density and weight are similar to those observed for the 1992/2010 and 1991/2009 rotations (see Hebert 2010a and Hebert 2010b).

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 calculating 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 1990/2011 rotation with the highest GHL is Subdistrict 103-40-001,002,004 (Tlevak Strait between Dall Island and Sukkwan Island) and the second highest GHL is in Subdistricts 113-51,52,53,54,59 (Figure 37). These 2 areas comprised 28% of the total regional GHL established for the 2011/2012 fishing season. Subdistricts 107-10 and 107-20 (Ernest Sound area) also contributed substantially to the regional GHL. Each of these top 4 areas had GHLs over 100,000 pounds and combined comprised 49% of the 2011/2012 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 2011/2012 GHLs are compared to those established for the 2008/2009 commercial fishery, of areas where a fishery occurred in 2008/2009, the GHL declined in 8 of 18 (see Figures 38–47). The GHL has increased in 6 of 18 areas over the same time period, and remained the same or close to the same in 4 of 18 areas.

Two areas (103-90 and 113-31,32,33) were not opened to the commercial fishery during the 2011/2012 season because the proposed GHLs were low, which increased the risk of exceeding the GHLs due to shifts in fishing effort between areas. Both of these areas are subject to predation by large numbers of sea otters, which are likely the cause of the decline in biomass and closure of the commercial fishery.

A survey was conducted in Tebenkof Bay (109-62) in 2011 to determine if sea cucumber abundance has rebounded since the last previous survey conducted in 2004. This area was first surveyed in 1992, when biomass was estimated at 1,025,000 pounds. Estimates of sea cucumber biomass in the area steadily declined until 2004 when the biomass was estimated at 3,732 pounds. The period of declining sea cucumber abundance was coincident with large numbers of sea otters inhabiting the area in the early 1990s. During the 2011 survey no sea cucumbers were observed. Sea otters numbering in the hundreds were observed in the area at the time of the survey.

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 and weight, in the absence of commercial harvest. Trends in these areas help to determine whether fluctuations of populations in fishery areas are due to harvest or environmental fluctuations.

Five control areas have been consistently surveyed annually since 2000, and 3 of these since 1998 (see Figure 2). Sea cucumber density in control areas has been steady or slightly decreasing for most areas. The slight downward trends suggest that current ocean conditions in the region may be less favorable for sea cucumbers than a decade ago, although conclusions cannot be made because the time series is short. Hebert 2010a reported that in 2010 sea cucumber density increased dramatically in 4 of 5 control areas, possibly due to a recruitment event. However, the increase was later revealed to be a calculation error and the corrected 2010 density estimates do not appear to be dramatically different than estimates from recent years (Figure 48). Density estimates for 2011 appear to be similar to those of 2010 in most areas; however a substantial increase is apparent in the Subdistrict 113-40 control area. Mean weight in 2011 for all control

areas appears similar to that of 2010 and there is no discernible trend in any area (Table 8; Figure 49).

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). For all of these areas, sea cucumber density appears to have decreased over time. However, a decrease in density is also apparent in the Subdistrict 101-27 control area, an area not known to be inhabited by sea otters. 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 only due to fishery mortality, and may include an environmental effect.

Biomass estimates in control areas follow very similar patterns over time as density estimates (Figure 50). This is because biomass estimates are calculated directly from density, habitat shoreline, and average weight estimates, but mean weight has remained stable over time and shoreline length is generally constant. Overall variance of biomass estimates (expressed as confidence intervals in Figure 50) 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 101 and 102 of Southeast Alaska.

Survey year	101-11,12,13	101-21	101-29	101-43	101-53	101-41,43,53	101-85	102-30	102-70 Thorne Bay	102-70-Clarence	102-70
1990	—	—	—	11.7	6.6	—	5.0	12.6	19.7	11.8	—
1993	—	—	—	7.4	9.2	—	6.6	13.7	—	4.9	—
1996	—	—	—	6.3	8.7	—	5.7	16.7	—	5.7	—
1999	—	—	19.7	—	—	13.4	7.4	20.3	—	—	8.8
2002	—	—	17.1	—	—	7.4	5.3	13.4	—	—	11.3
2005	—	—	12.4	—	—	7.4	5.3	10.4	—	—	9.2
2008	—	15.3	8.0	—	—	9.2	4.7	9.2	—	—	12.9
2011	1.8	—	8.3	—	—	5.5	5.6	9.2	—	—	10.1

Table 2.–Average sea cucumbers per meter of shoreline ("density") from surveys in commercial fishery subdistricts 103, 104 and 105 of Southeast Alaska.

Survey year	103-40-002	103-40-004	103-40-002,004	103-40-001,002,004	103-70	103-90-001	103-90-002	103-90	104-10,20,30
1990	9.9	8.9	—	—	—	16.2	—	—	—
1993	—	7.0	—	—	5.8	8.4	—	—	—
1996	—	11.2	—	—	8.2	4.1	11.7	—	—
1999	—	—	10.9	—	5.6	—	—	13.6	—
2002	—	—	—	12.6	2.9	—	—	10.3	—
2005	—	—	—	10.7	—	—	—	7.3	9.0
2008	—	—	—	6.7	—	—	—	3.7	7.6
2011	—	—	—	5.8	—	—	—	1.5	4.2

Table 3.–Average sea cucumbers per meter of shoreline ("density") from surveys in commercial fishery subdistricts 105, 106, 107, 108, 109, 111 of Southeast Alaska.

Survey year	105-10,20	106-42,108-10,40	107-10	107-20	107-30,35	107-40, 45	108-10,20,40	109-10,11	111-40,41
1990	3.4	—	—	—	—	—	—	—	—
1993	—	—	—	—	—	—	—	—	—
1996	—	—	20.5	8.6	—	—	—	—	—
1999	—	—	22.0	6.7	6.9	—	—	—	—
2002	—	2.6	22.4	9.1	4.1	—	—	3.4	—
2005	—	—	17.8	10.9	7.2	—	6.4	5.2	—
2008	—	—	16.8	8.0	5.6	1.6	6.0	4.5	0.5
2011	—	—	20.3	8.9	6.7	1.5	8.6	3.9	—

Table 4.–Average sea cucumbers per meter of shoreline (“density”) from surveys in commercial fishery subdistricts 112–114 of Southeast Alaska.

Survey year	112-15	112-16, 17, 63, 65	113-31	113-32	113-33	113-34	113-31, 32, 33	113-38, 41	113-51,52,53,54,59	114-25,80
1990	—	—	22.3	—	19.7	—	—	4.8	—	—
1993	—	—	14.5	7.1	6.9	3.5	—	11.0	20.1	—
1996	—	—	3.9	1.2	3.1	—	—	3.3	9.0	—
1999	—	—	—	—	—	—	7.2	7.1	18.0	—
2002	—	12.2	—	—	—	—	6.6	4.7	9.8	—
2005	2.9	8.5	—	—	—	—	3.7	4.9	11.1	11.5
2008	—	10.8	—	—	—	—	3.2	3.3	10.6	12.9
2011	—	7.8	—	—	—	—	1.6	2.3	15.7	12.9

Table 5.–Average sea cucumber weight (grams) from surveys in commercial fishery subdistricts 101 and 102 of Southeast Alaska.

Survey year	101-11,12,13	101-21	101-29	101-43	101-53	101-41,43,53	101-85	102-30	102-70 Thorne Bay	102-70-Clarence	102-70
1990	—	—	—	188	113	—	181	180	222	222	—
1993	—	—	—	199	89	—	164	175	—	228	—
1996	—	—	—	202	97	—	207	188	—	215	—
1999	—	—	188	—	—	134	173	176	—	—	212
2002	—	—	196	—	—	148	200	189	—	—	203
2005	—	—	215	—	—	131	179	177	—	—	200
2008	—	299	208	—	—	152	184	197	—	—	205
2011	237	—	181	—	—	173	220	185	—	—	208

Table 6.–Average sea cucumber weight (grams) from surveys in commercial fishery subdistricts 103–105of Southeast Alaska.

Survey year	103-40-002	103-40-004	103-40-002,004	103-40-001,002,004	103-70	103-90-001	103-90-002	103-90	104-10,20,30	105-10,20
1990	209	243	—	—	—	270	—	—	—	285
1993	—	253	—	—	219	330	—	—	—	—
1996	—	243	—	—	215	222	184	—	—	—
1999	—	—	220	—	222	—	—	229	—	—
2002	—	—	—	230	217	—	—	239	—	—
2005	—	—	—	235	—	—	—	255	244	—
2008	—	—	—	236	—	—	—	234	239	—
2011	—	—	—	256	—	—	—	219	248	—

Table 7.–Average sea cucumber weight (grams) from surveys in commercial fishery subdistricts 106, 107, 108, 109, 111 and 112 of Southeast Alaska.

Survey year	106-42,108-10,40	107-10	107-20	107-30,35	107-40, 45	108-10,20,40	109-10,11	111-40,41	112-15	112-16, 17, 63, 65
1990	—	—	—	—	—	—	—	—	—	—
1993	—	—	—	—	—	—	—	—	—	—
1996	—	158	124	—	—	—	—	—	—	—
1999	—	135	150	250	—	—	—	—	—	—
2002	153	170	165	261	—	—	153	—	—	173
2005	—	180	153	245	—	153	198	—	196	209
2008	—	152	134	188	247	134	173	211	—	189
2011	—	202	177	242	212	160	173	—	—	207

Table 8.–Average sea cucumber weight (grams) from surveys in commercial fishery subdistricts 113 and 114 of Southeast Alaska.

Survey year	113-31	113-32	113-33	113-34	113-31, 32, 33	113-38, 41	113-51,52,53,54,59	114-25,80
1990	223	—	213	—	—	233	187	—
1993	247	205	236	231	—	230	158	—
1996	204	231	226		—	253	207	—
1999	—	—	—	—	200	215	195	—
2002	—	—	—	—	207	230	201	—
2005	—	—	—	—	260	224	210	222
2008	—	—	—	—	205	226	231	208
2011	—	—	—	—	223	220	184	213

Table 9.–Total sea cucumber biomass in pounds for Southeast Alaska fishery subdistricts 101 and 102.

Survey year	101-11,12,13	101-21	101-29	101-43	101-53	101-41,43,53	101-85	102-30	102-70 Thorne Bay	102-70-Clarence	102-70
1990	—	—	—	258,288	101,222	—	179,776	790,709	556,056	265,639	—
1993	—	—	—	173,011	110,976	—	212,037	835,910	—	114,616	—
1996	—	—	—	149,373	114,878	—	233,345	1,101,509	—	124,832	—
1999	—	—	391,596	—	—	559,247	252,844	1,250,629	—	—	427,249
2002	—	—	352,656	—	—	342,626	208,029	883,613	—	—	528,077
2005	—	—	281,154	—	—	301,486	186,766	642,209	—	—	421,698
2008	—	117,049	176,221	—	—	435,608	169,774	633,933	—	—	604,711
2011	131,992	—	157,923	—	—	294,875	243,257	594,613	—	—	484,127

Table 10.–Total sea cucumber biomass in pounds for Southeast Alaska fishery subdistricts 103, 104 and 105.

Survey year	103-40-002	103-40-004	103-40-002,004	103-40-001,002,004	103-70	103-90-001	103-90-002	103-90	104-10,20,30	105-10,20
1990	530,332	473,060	—	—	—	1,516,436	—	—	—	324,774
1993	—	383,411	—	—	259,406	957,304	—	—	—	—
1996	—	590,924	—	—	357,374	313,774	1,446,256	—	—	—
1999	—	—	1,135,817	—	253,929	—	—	3,180,772	—	—
2002	—	—	—	2,004,517	126,839	—	—	2,495,521	—	—
2005	—	—	—	1,746,501	—	—	—	1,904,359	800,643	—
2008	—	—	—	1,098,970	—	—	—	884,331	664,948	—
2011	—	—	—	1,032,330	—	—	—	325,730	379,472	—

Table 11.–Total sea cucumber biomass in pounds for Southeast Alaska fishery subdistricts 106, 107, 108, 109, 111, and 112.

Survey year	106-42,108-10,40	107-10	107-20	107-30,35	107-40, 45	108-10,20,40	109-10,11	111-40,41	112-15	112-16, 17, 63, 65
1990	—	—	—	—	—	—	—	—	—	—
1993	—	—	—	—	—	—	—	—	—	—
1996	—	759,316	504,424	—	—	—	—	—	—	—
1999	—	697,616	473,817	430,701	—	—	—	—	—	—
2002	183,617	895,431	711,186	265,595	—	—	113,995	—	—	613,625
2005	—	750,699	783,430	438,229	—	176,902	227,341	—	39,553	516,326
2008	—	598,850	504,619	260,789	156,629	144,939	172,331	27,240	—	589,387
2011	—	964,974	742,401	406,108	128,731	250,353	148,876	—	—	469,192

Table 12.–Total sea cucumber biomass in pounds for Southeast Alaska fishery subdistricts 113 and 114.

Survey year	113-31	113-32	113-33	113-34	113-31, 32, 33	113-38, 41	113-51,52,53,54,59	114-25,80
1990	1,548,525	—	749,975	—	—	249,634	1,619,115	—
1993	1,108,633	154,037	293,522	103,085	—	567,387	1,104,681	—
1996	246,932	28,777	124,776	—	—	186,756	642,788	—
1999	—	—	—	—	854,013	339,050	1,223,732	—
2002	—	—	—	—	819,367	239,358	684,585	—
2005	—	—	—	—	579,753	243,898	811,188	406,799
2008	—	—	—	—	391,966	166,210	848,788	234,772
2011	—	—	—	—	207,333	110,535	1,005,909	240,679

Table 13.–Linear shoreline measurement in meters of cucumber habitat used to estimate biomass in Southeast Alaska fishery subdistricts 101 and 102.

Survey year	101-11,12,13	101-21	101-29	101-43	101-53	101-41,43,53	101-85	102-30	102-70 Thorne Bay	102-70-Clarence	102-70
1990	—	—	—	53,442	61,570	—	89,265	159,001	57,765	46,300	—
1993	—	—	—	53,442	61,570	—	89,265	159,001	—	46,300	—
1996	—	—	—	53,442	61,570	—	89,265	159,001	—	46,300	—
1999	—	—	47,874	—	—	141,033	89,268	159,004	—	—	104,065
2002	—	—	47,874	—	—	141,033	89,268	159,001	—	—	104,065
2005	—	—	47,874	—	—	141,033	89,268	159,001	—	—	104,065
2008	—	11,622	47,874	—	—	141,033	89,268	159,001	—	—	104,065
2011	139,341	—	47,875	—	—	141,033	89,269	159,002	—	—	104,065

Table 14.–Linear shoreline measurement in meters of cucumber habitat used to estimate biomass in Southeast Alaska fishery subdistricts 103, 104, and 105.

Survey year	103-40-002	103-40-004	103-40-002,004	103-40-001,002,004	103-70	103-90-001	103-90-002	103-90	104-10,20,30	105-10,20
1990	116,664	99,000	—	—	—	156,957	—	—	—	154,170
1993	—	99,000	—	—	92,600	156,957	—	—	—	—
1996	—	99,000	—	—	92,600	156,957	305,024	—	—	—
1999	—	—	215,664	—	92,600	—	—	461,981	—	—
2002	—	—	—	313,967	92,601	—	—	461,981	—	—
2005	—	—	—	313,967	—	—	—	461,981	165,590	—
2008	—	—	—	313,967	—	—	—	461,981	165,590	—
2011	—	—	—	313,967	—	—	—	461,981	165,590	—

Table 15.–Linear shoreline measurement in meters of cucumber habitat used to estimate biomass in Southeast Alaska fishery subdistricts 106, 107, 108, 109, 111, and 112.

Survey year	106-42,108-10,40	107-10	107-20	107-30,35	107-40, 45	108-10,20,40	109-10,11	111-40,41	112-15	112-16, 17, 63, 65
1990	—	—	—	—	—	—	—	—	—	—
1993	—	—	—	—	—	—	—	—	—	—
1996	—	106,675	213,906	—	—	—	—	—	—	—
1999	—	106,675	213,906	113,146	—	—	—	—	—	—
2002	207,431	106,676	213,907	113,147	—	—	99,767	—	—	131,431
2005	—	106,676	213,907	113,147	—	82,265	99,767	—	31,395	131,431
2008	—	106,676	213,907	113,147	179,577	82,265	99,767	114,230	—	131,431
2011	—	106,675	213,906	113,146	179,578	82,265	99,767	—	—	131,432

Table 16.–Linear shoreline measurement in meters of cucumber habitat used to estimate biomass in Southeast Alaska fishery subdistricts 113 and 114.

Survey year	113-31	113-32	113-33	113-34	113-31, 32, 33	113-38, 41	113-51,52,53,54,59	114-25,80
1990	141,122	—	81,488	—	—	101,304	157,880	—
1993	141,122	47,946	81,488	56,949	—	101,304	157,880	—
1996	141,122	47,946	81,488	—	—	101,304	157,882	—
1999	—	—	—	—	270,556	101,304	157,883	—
2002	—	—	—	—	270,556	101,305	157,884	—
2005	—	—	—	—	270,556	101,305	157,884	72,284
2008	—	—	—	—	270,556	101,305	157,885	39,757
2011	—	—	—	—	270,556	101,304	157,880	39,758

Table 17.–Potential commercial harvest levels in pounds based on 6.2% annual harvest rate for fishery subdistricts 101 and 102 in Southeast Alaska. The abbreviation “nf” signifies no fishery in that area and bold values signify some harvest from a subsection of currently defined fishery area.

Survey year	101-11,12,13	101-21	101-29	101-43	101-53	101-41,43,53	101-85	102-30	102-70 Thorne Bay	102-70-Clarence	102-70
1990	—	—	—	—	—	**35,522**	16,570	139,458	n/f	57,797	—
1993	—	—	—	—	—	**87,196**	56,966	147,385	—	40,303	—
1996	—	—	—	—	—	**38,343**	34,932	174,043	—	12,718	—
1999	—	—	47,407	—	—	76,096	27,426	188,875	—	—	59,551
2002	—	—	88,380	—	—	50,358	18,940	128,595	—	—	86,118
2005	—	—	32,542	—	—	39,027	18,941	94,691	—	—	52,062
2008	—	n/f	23,018	—	—	56,867	n/f	101,068	—	—	93,586
2011	n/f	—	27,595	—	—	44,245	21,937	93,315	—	—	79,158

Table 18.–Potential commercial harvest levels in pounds based on 6.2% annual harvest rate for fishery subdistricts 103, 104 and 105 in Southeast Alaska. The abbreviation “nf” signifies no fishery in that area and bold values signify some harvest from a subsection of currently defined fishery area.

Survey year	103-40-002	103-40-004	103-40-002,004	103-40-001,002,004	103-70	103-90-001	103-90-002	103-90	104-10,20,30	105-10,20
1990	n/f	74,271	—	—	—	n/f	—	—	—	19,389
1993	—	57,499	—	—	27,756	n/f	—	—	—	—
1996	—	92,232	—	—	43,205	n/f	181,022	—	—	—
1999	—	—	158,818	—	22,157	—	—	462,844	—	—
2002	—	—	—	310,208	—	—	—	333,304	—	—
2005	—	—	—	267,909	—	—	—	202,464	115,312	—
2008	—	—	—	163,838	—	—	—	92,812	89,565	—
2011	—	—	—	152,674	—	—	—	n/f	39,510	—

Table 19.–Potential commercial harvest levels in pounds based on 6.2% annual harvest rate for fishery subdistricts 106, 107, 108, 109, 111 and 112 in Southeast Alaska. The abbreviation "nf" signifies no fishery in that area and bold values signify some harvest from a subsection of currently defined fishery area.

Survey year	106-42,108-10,40	107-10	107-20	107-30,35	107-40, 45	108-10,20,40	109-10,11	111-40,41	112-15	112-16, 17, 63, 65
1990	—	—	—	—	—	—	—	—	—	—
1993	—	—	—	—	—	—	—	—	—	—
1996	—	94,817	70,891	—	—	—	—	—	—	—
1999	—	94,998	64,179	57,983	—	—	—	—	—	—
2002	22,236	109,390	100,713	39,306	—	—	11,968	—	—	97,441
2005	—	85,084	111,623	58,476	—	22,638	22,246	—	n/f	69,634
2008	—	58,588	69,729	24,789	10,214	14,859	21,797	n/f	—	85,244
2011	—	109,518	102,480	59,571	17,760	29,462	21,236	—	—	61,125

Table 20.–Potential commercial harvest levels in pounds based on 6.2% annual harvest rate for fishery subdistricts 106, 107, 108, 109 and 111 in Southeast Alaska. The abbreviation "nf" signifies no fishery in that area and bold values signify some harvest from a subsection of currently defined fishery area.

Survey year	113-31	113-32	113-33	113-34	113-31, 32, 33	113-38, 41	113-51,52,53,54,59	114-25,80
1990	—	—	—	—	**216,027**	94,699	146,947	—
1993	—	—	—	—	**225,724**	82,949	238,565	—
1996	—	—	—	—	**35,294**	30,598	101,694	—
1999	—	—	—	—	128,907	31,928	145,214	—
2002	—	—	—	—	112,985	29,076	100,422	—
2005	—	—	—	—	84,852	28,751	97,526	33,953
2008	—	—	—	—	58,642	16,478	88,938	32,537
2011	—	—	—	—	n/f	11,460	126,577	26,211

Table 21.–Actual commercial fishery guideline harvest levels (GHLs) in pounds for fishery subdistricts 101 and 102 in Southeast Alaska. The abbreviation "nf" signifies no fishery in that area and year.

Survey year	101-11,12,13	101-21	101-29	101-43	101-53	101-41,43,53	101-85	102-30	102-70 Thorne Bay	102-70-Clarence	102-70
1990	—	—	—	—	14,289	—	15,037	131,073	n/f	55,247	—
1993	—	—	—	14,560	20,609	—	37,950	150,977	—	15,962	—
1996	—	—	—	18,500	20,700	—	32,900	180,100	—	16,000	—
1999	—	—	44,000	—	—	81,000	27,000	188,000	—	—	64,000
2002	—	—	40,400	—	—	49,800	21,000	129,900	—	—	84,200
2005	—	—	35,500	—	—	43,900	20,800	95,400	—	—	55,600
2008	—	n/f	23,900	—	—	62,700	n/f	97,700	—	—	91,500
2011	n/f	—	21,400	—	—	42,400	23,700	90,300	—	—	73,300

Table 22.–Actual commercial fishery guideline harvest levels (GHLs) in pounds for fishery subdistricts 103, 104, and 105 in Southeast Alaska. The abbreviation “nf” signifies no fishery in that area and year.

Survey year	103-40-002	103-40-004	103-40-002,004	103-40-001,002,004	103-70	103-90-001	103-90-002	103-90	104-10,20,30	105-10,20
1990	n/f	71,084	—	—	—	n/f	—	—	—	5,805
1993	—	47,834	—	—	24,774	n/f	—	—	—	—
1996	—	78,400	—	—	46,000	n/f	202,000	—	—	—
1999	—	—	169,000	—	24,000	—	—	468,000	—	—
2002	—	—	—	306,800	—	—	—	339,800	—	—
2005	—	—	—	267,800	—	—	—	201,700	110,300	—
2008	—	—	—	173,300	—	—	—	101,600	83,100	—
2011	—	—	—	147,000	—	—	—	n/f	44,150	—

Table 23.–Actual commercial fishery guideline harvest levels (GHLs) in pounds for fishery subdistricts 106, 107,108, 109, 111, and 112 in Southeast Alaska. The abbreviation “nf” signifies no fishery in that area and year.

Survey year	106-42,108-10,40	107-10	107-20	107-30,35	107-40, 45	108-10,20,40	109-10,11	111-40,41	112-15	112-16, 17, 63, 65
1990	—	—	—	—	—	—	—	—	—	—
1993	—	—	—	—	—	—	—	—	—	—
1996	—	97,400	75,600	—	—	—	—	—	—	—
1999	—	81,000	68,000	54,000	—	—	—	—	—	—
2002	22,700	112,300	92,500	30,600	—	—	13,400	—	—	91,700
2005	—	86,700	112,200	55,200	—	22,300	29,400	—	n/f	67,200
2008	—	60,800	65,200	25,700	14,200	17,800	21,900	n/f	—	83,200
2011	—	106,650	105,000	47,900	15,900	29,000	14,150	—	—	60,200

Table 24.–Actual commercial fishery guideline harvest levels (GHLs) in pounds for fishery subdistricts 113 and 114 in Southeast Alaska. The abbreviation “nf” signifies no fishery in that area and year.

Survey year	113-31	113-32	113-33	113-34	113-31, 32, 33	113-38, 41	113-51,52,53,54,59	114-25,80
1990	162,996		31,640	—	—	88,165	151,010	—
1993	124,923	18,023	47,334	20,652	—	74,825	209,744	—
1996	25,000	4,300	15,500	—	—	26,300	100,600	—
1999	—	—	—	—	124,000	35,000	153,000	—
2002	—	—	—	—	113,800	31,100	96,700	—
2005	—	—	—	—	85,200	31,400	99,400	31,750
2008	—	—	—	—	56,700	17,800	98,300	26,700
2011	—	—	—	—	n/f	12,400	129,400	27,150

Table 25.–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	11.0	9.8	11.0	22.3	2.1
2011	11.5	7.7	13.8	21.7	4.6

Table 26.–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
2011	203	306	273	339	227

Table 27.–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	291,193	113,683	107,819	493,769	24,113
2011	279,566	99,663	161,383	510,523	53,307

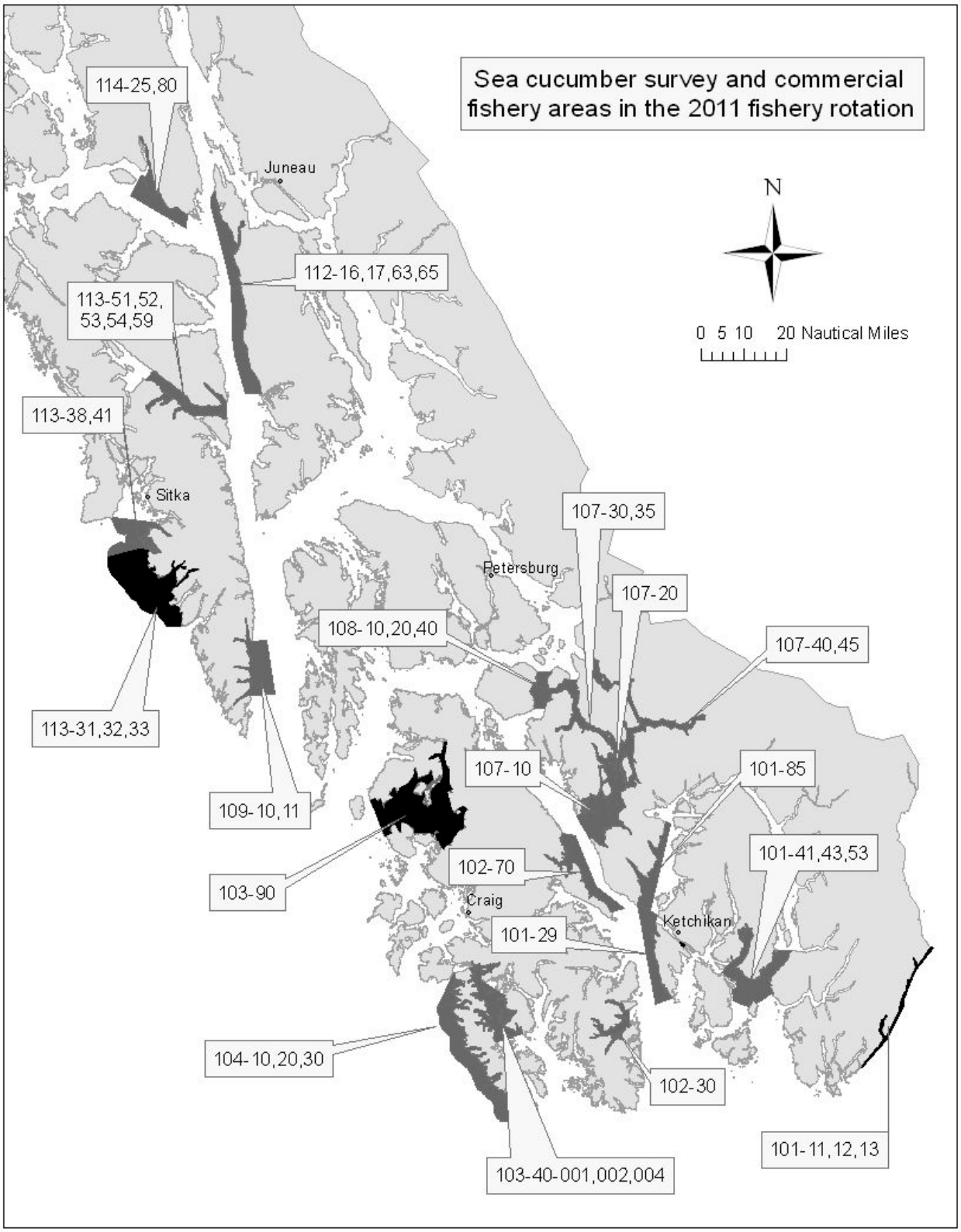


Figure 1.–Location of Southeast Alaska sea cucumber commercial fishery subdistricts in 1990/2011 fishery rotation. Areas shaded gray represent areas surveyed in 2011 and opened in 2011/2012 commercial fishery. Black areas were surveyed but not opened for the 2011/2012 season.

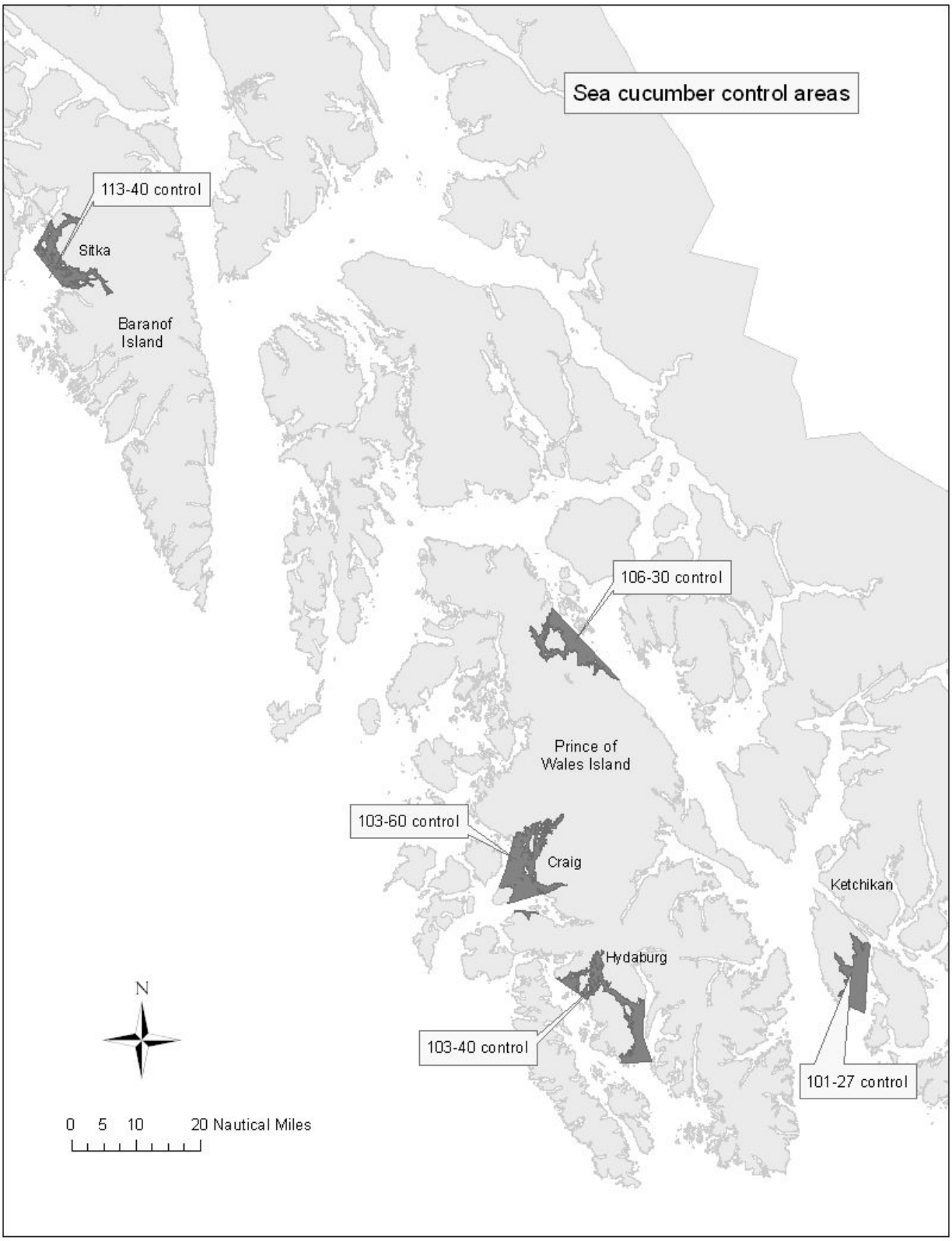


Figure 2.–Location of sea cucumber control (closed to commercial harvest) areas in Southeast Alaska

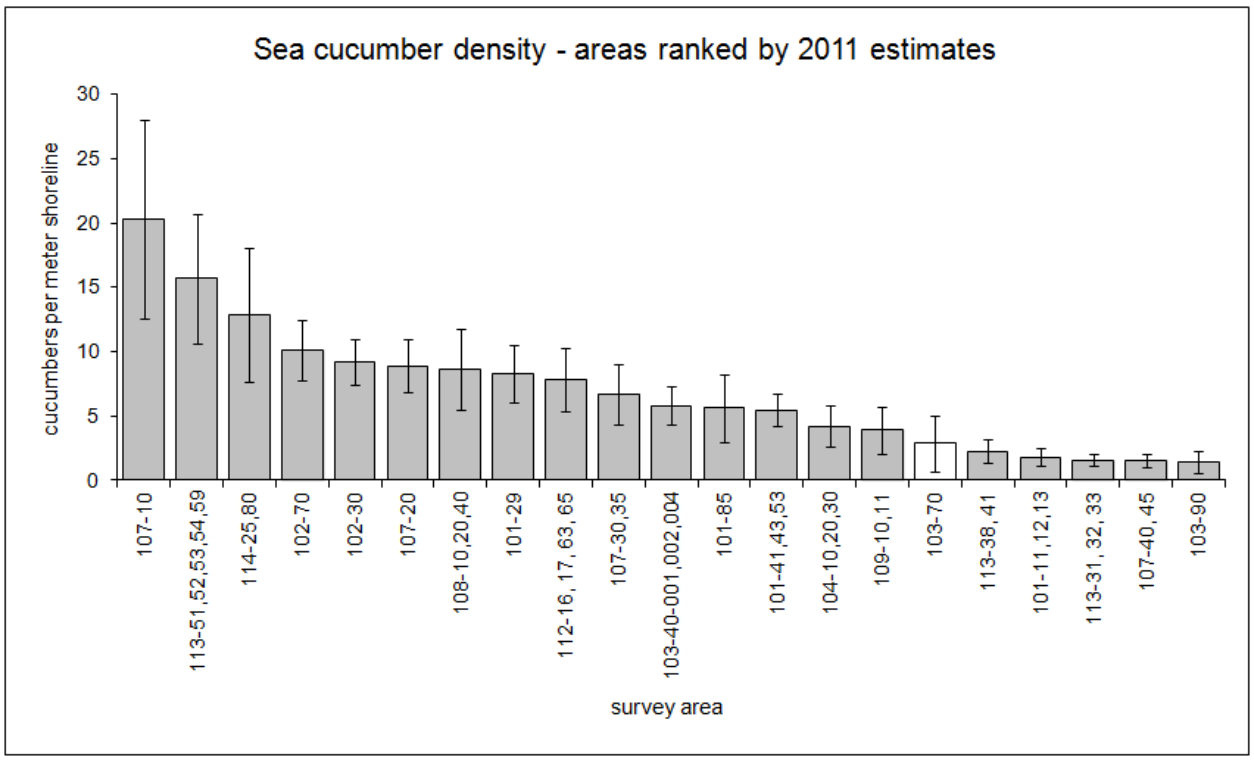


Figure 3.–Estimated sea cucumbers per meter of shoreline in Southeast Alaska, ranked by survey area using 2011 estimates. Bars without shading represent values from surveys prior to 2011 as no survey was conducted in 2011, and are shown for comparison. Error bars represent 90% confidence intervals.

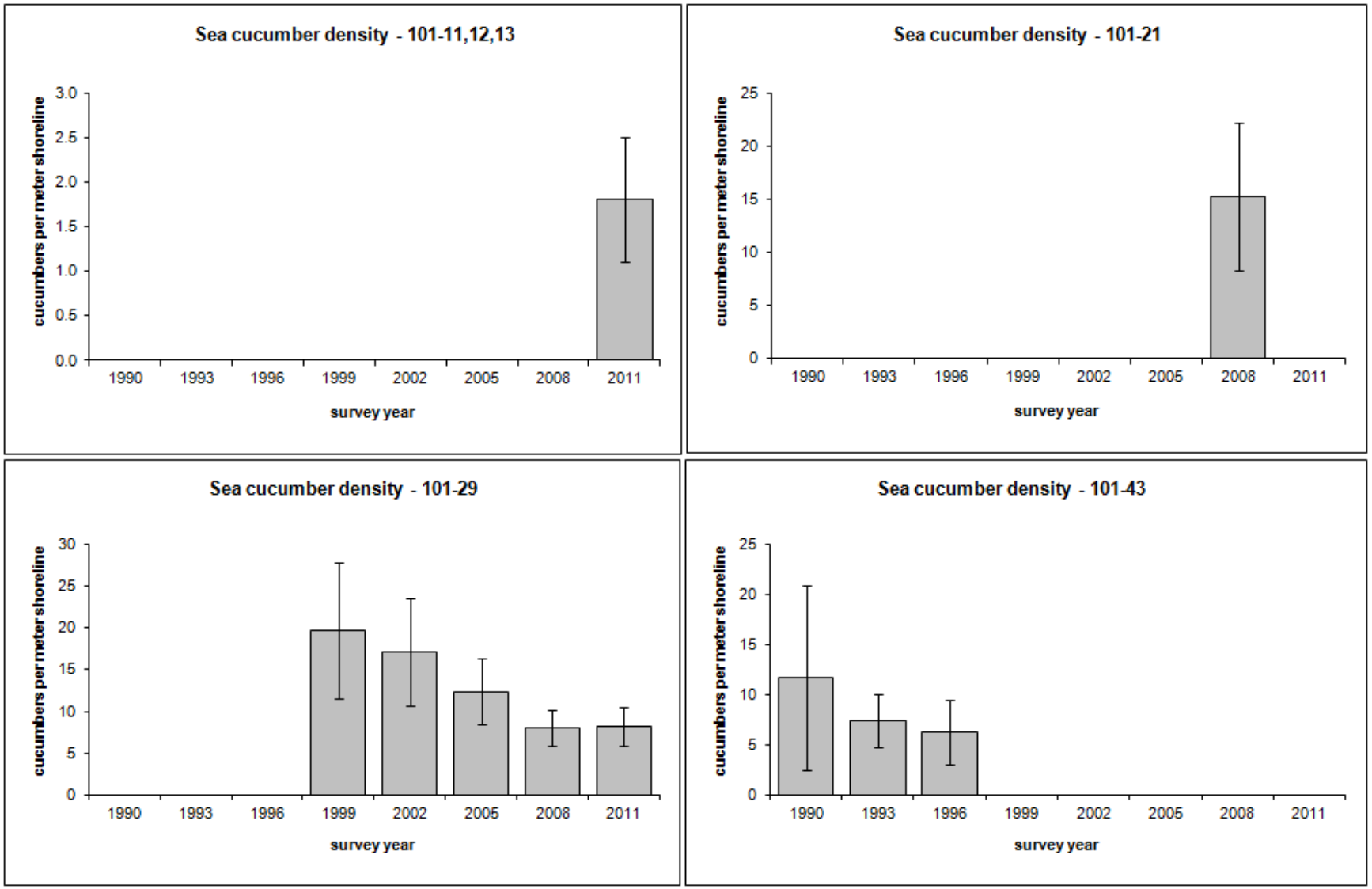


Figure 4.–Average number of sea cucumbers per meter of shoreline from surveys in commercial fishery Subdistricts 101-11,12,13, Subdistrict 101-21, Subdistrict 101-29, and Subdistrict 101-43 in Southeast Alaska. Error bars represent 90% confidence intervals.

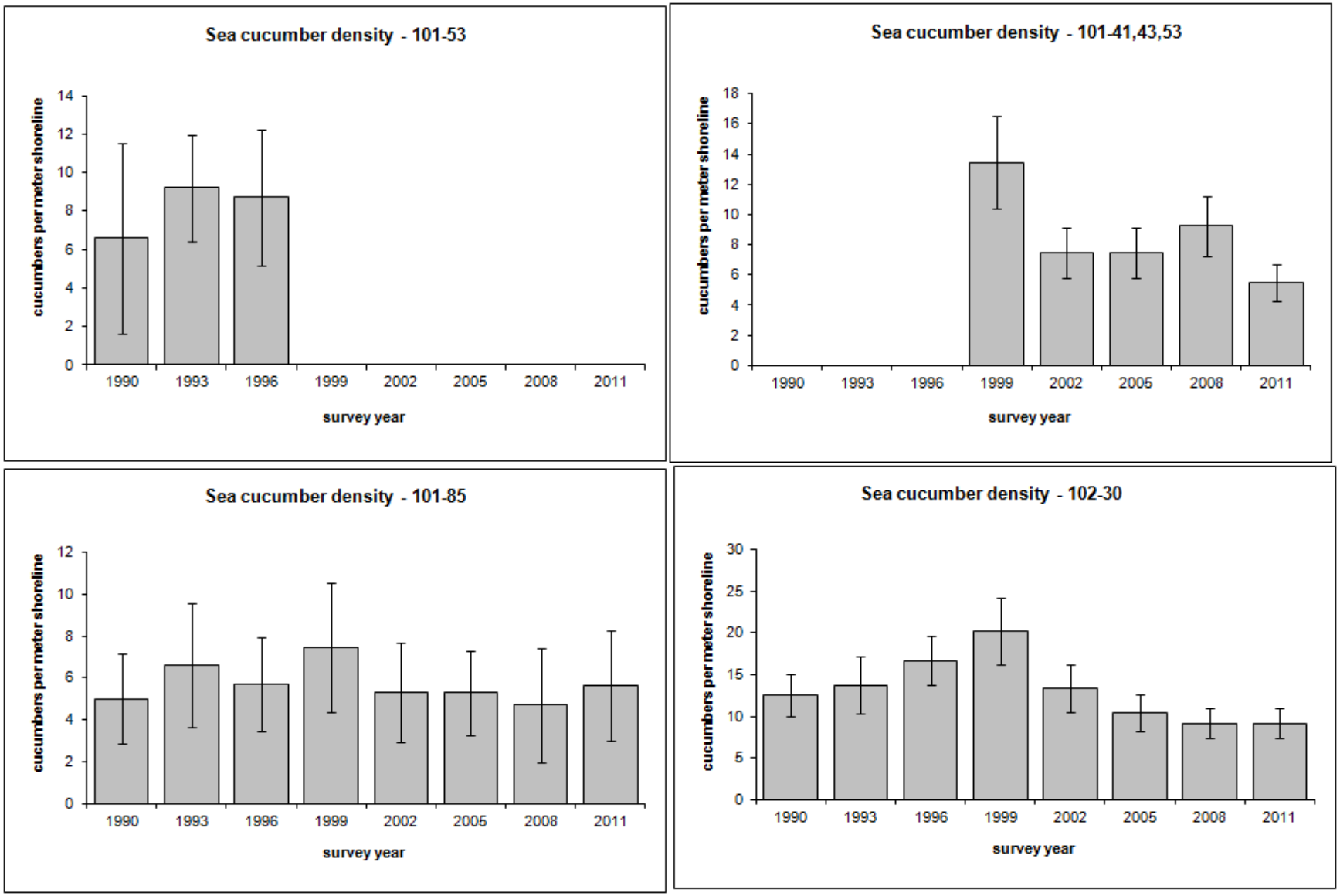


Figure 5.–Average number of sea cucumbers per meter of shoreline from surveys in commercial fishery Subdistrict 101-53, Subdistricts 101-41,43,53, Subdistrict 101-85, and Subdistrict 102-30 in Southeast Alaska. Error bars represent 90% confidence intervals.

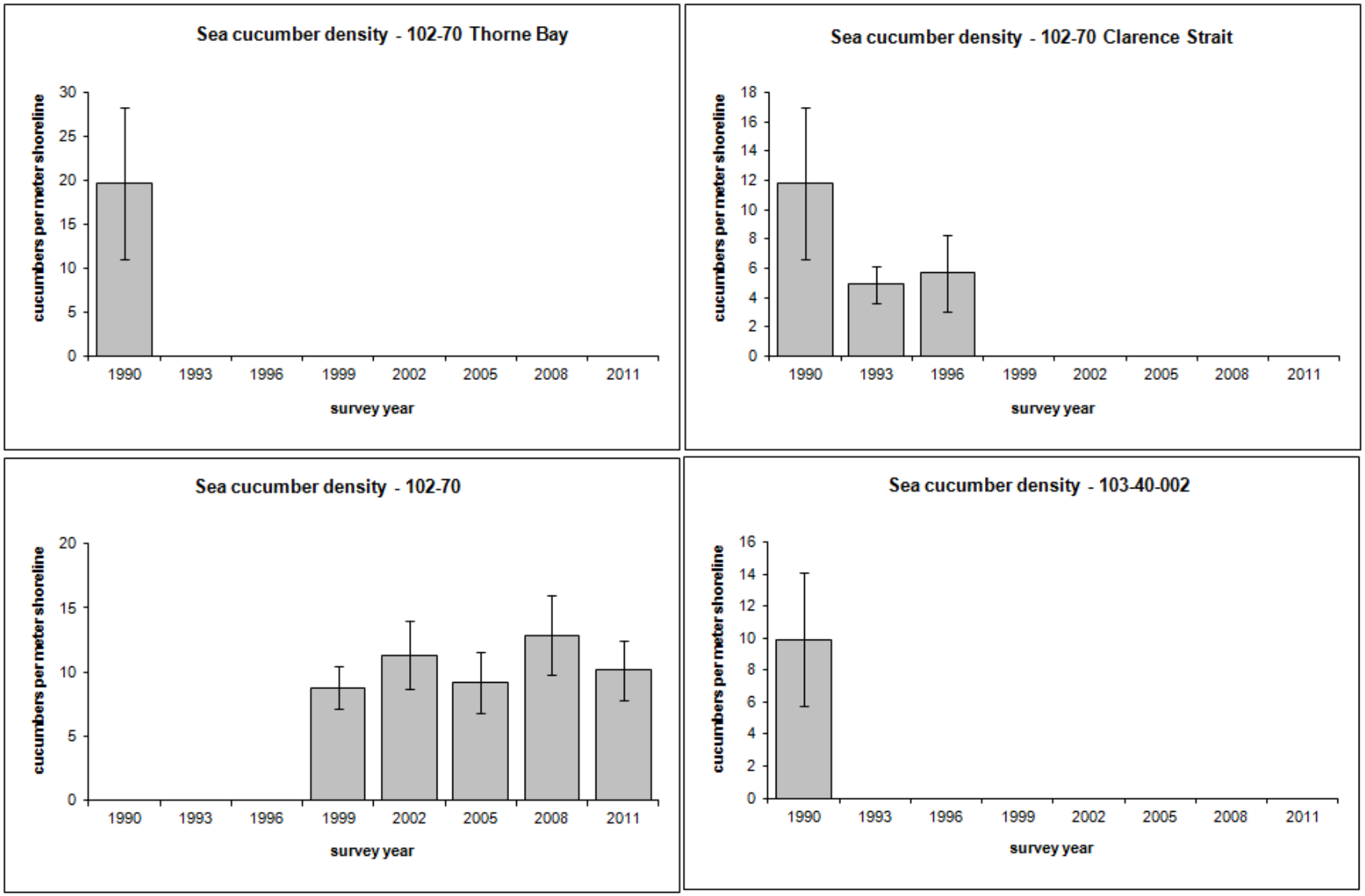


Figure 6.–Average number of sea cucumbers per meter of shoreline from surveys in commercial fishery Subdistrict 102-70 Thorne Bay, Subdistrict 102-70 Clarence Strait, Subdistrict 102-70, and Subdistricts 103-40-002. Error bars represent 90% confidence intervals.

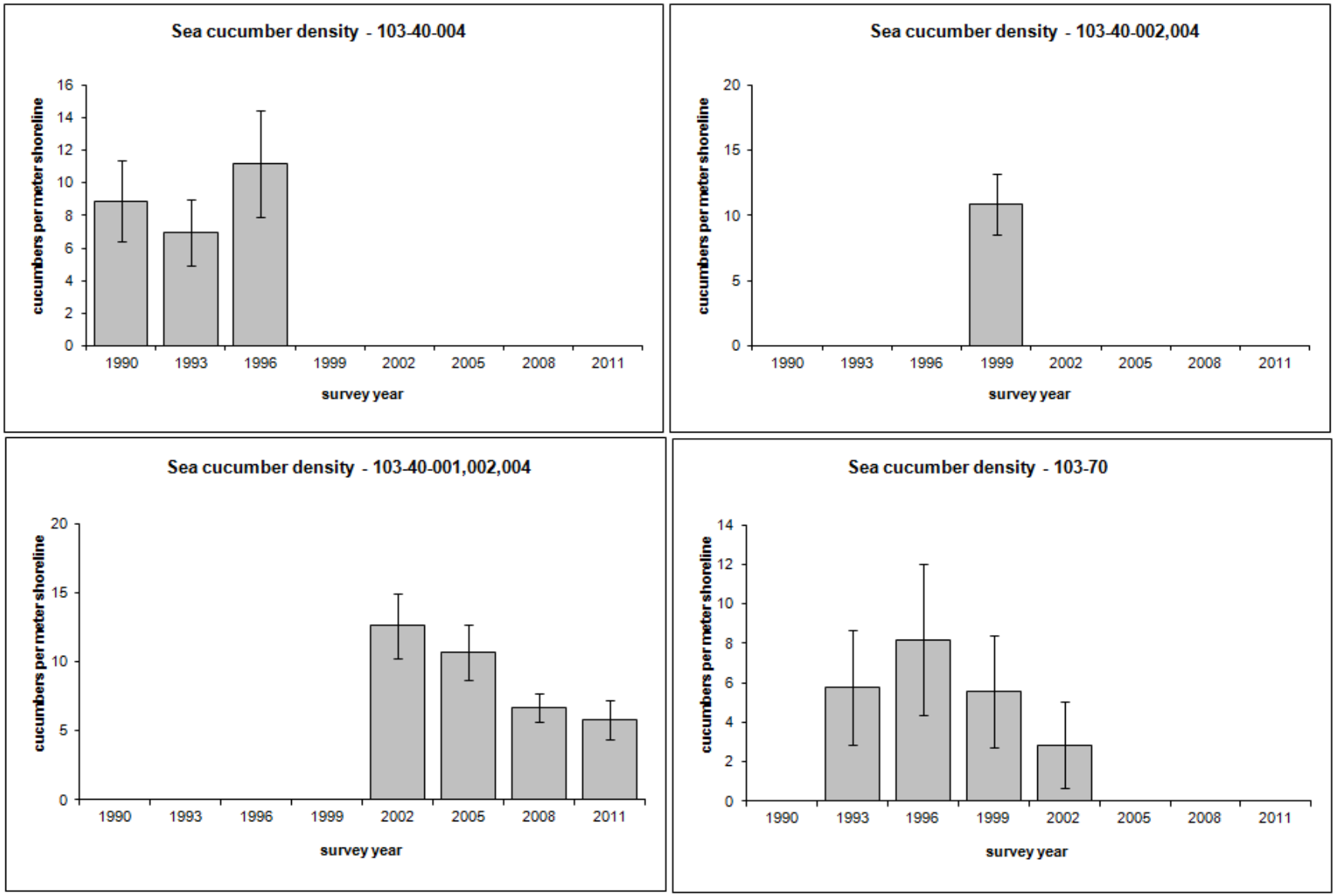


Figure 7.–Average number of sea cucumbers per meter of shoreline from surveys in commercial fishery Subdistrict 103-40-004, Subdistrict 103-40-002,004, Subdistrict 103-40-001,002,004, and Subdistrict 103-70 in Southeast Alaska. Error bars represent 90% confidence intervals.

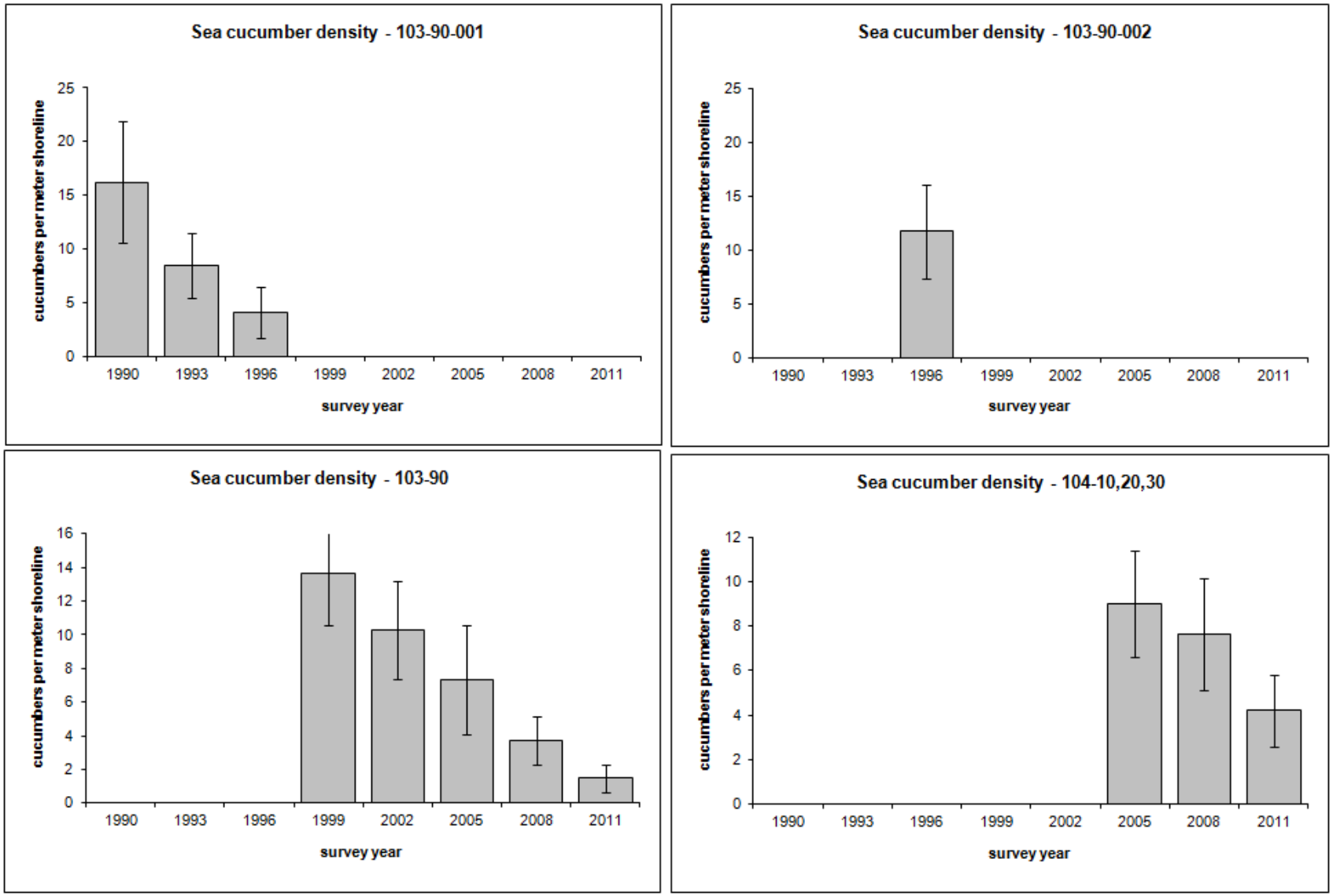


Figure 8.–Average number of sea cucumbers per meter of shoreline from surveys in commercial fishery Subdistrict 103-90-001, Subdistricts 103-90-002, Subdistrict 103-90, and Subdistricts 104-10,20,30, in Southeast Alaska. Error bars represent 90% confidence intervals.

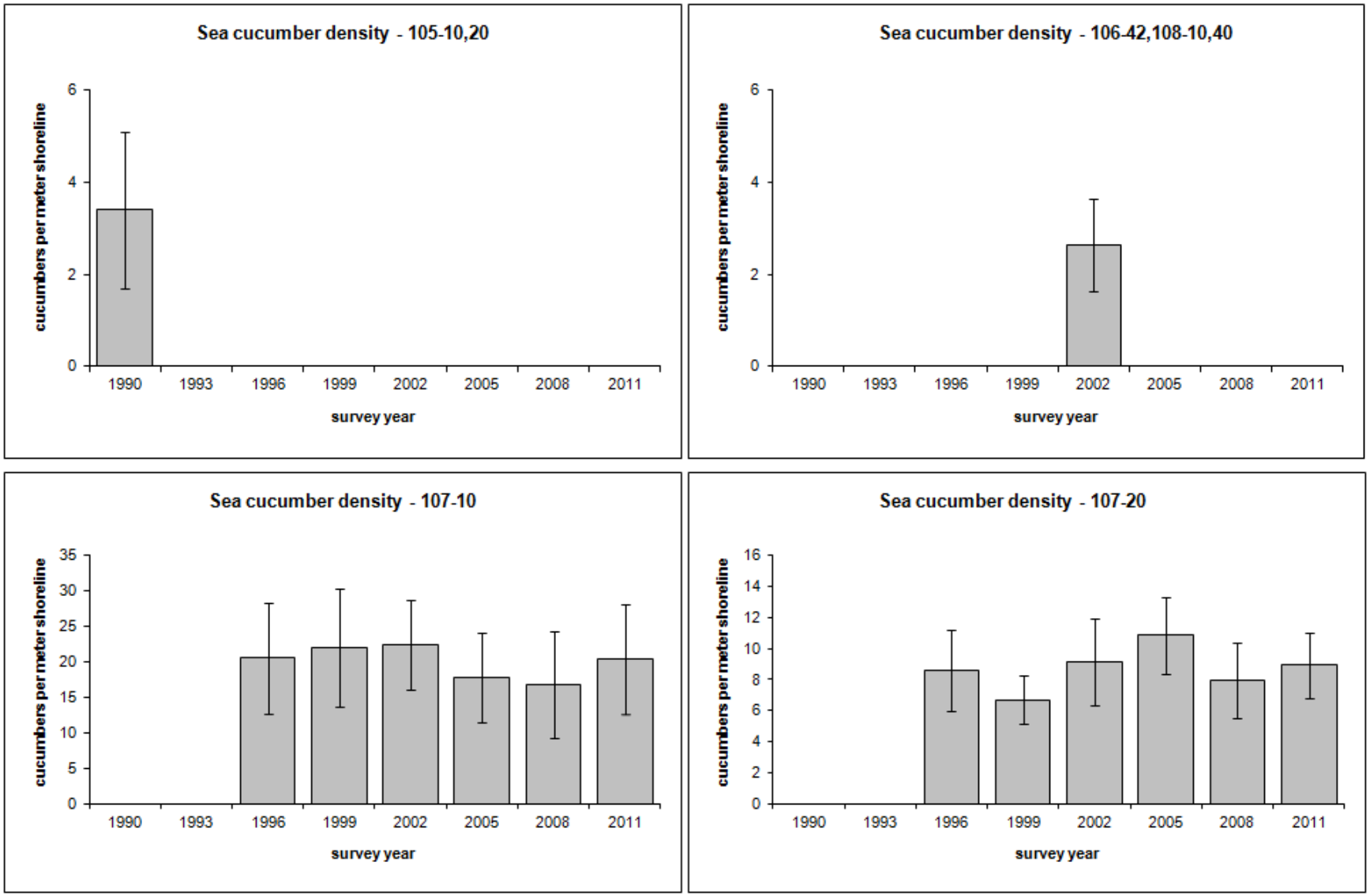


Figure 9.–Average number of sea cucumbers per meter of shoreline from surveys in commercial fishery Subdistricts 105-10,20, Subdistricts 106-42,108-10,40, Subdistrict 107-10, and Subdistrict 107-20-10, in Southeast Alaska. Error bars represent 90% confidence intervals.

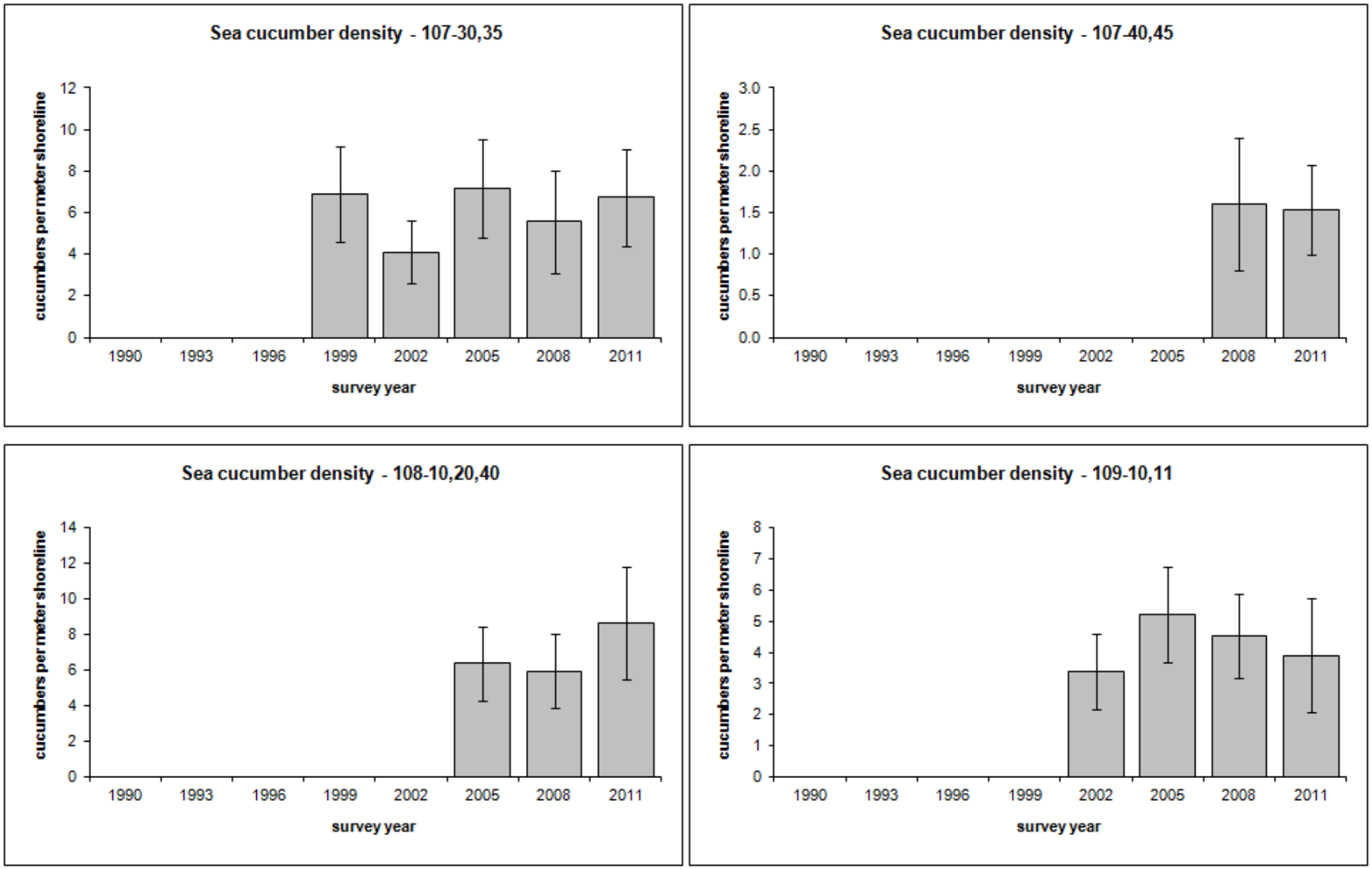


Figure 10.–Average number of sea cucumbers per meter of shoreline from surveys in commercial fishery Subdistricts 107-30,35, Subdistricts 107-40,45, Subdistricts 108-10,20,40, and Subdistricts 109-10,11, in Southeast Alaska. Error bars represent 90% confidence intervals.

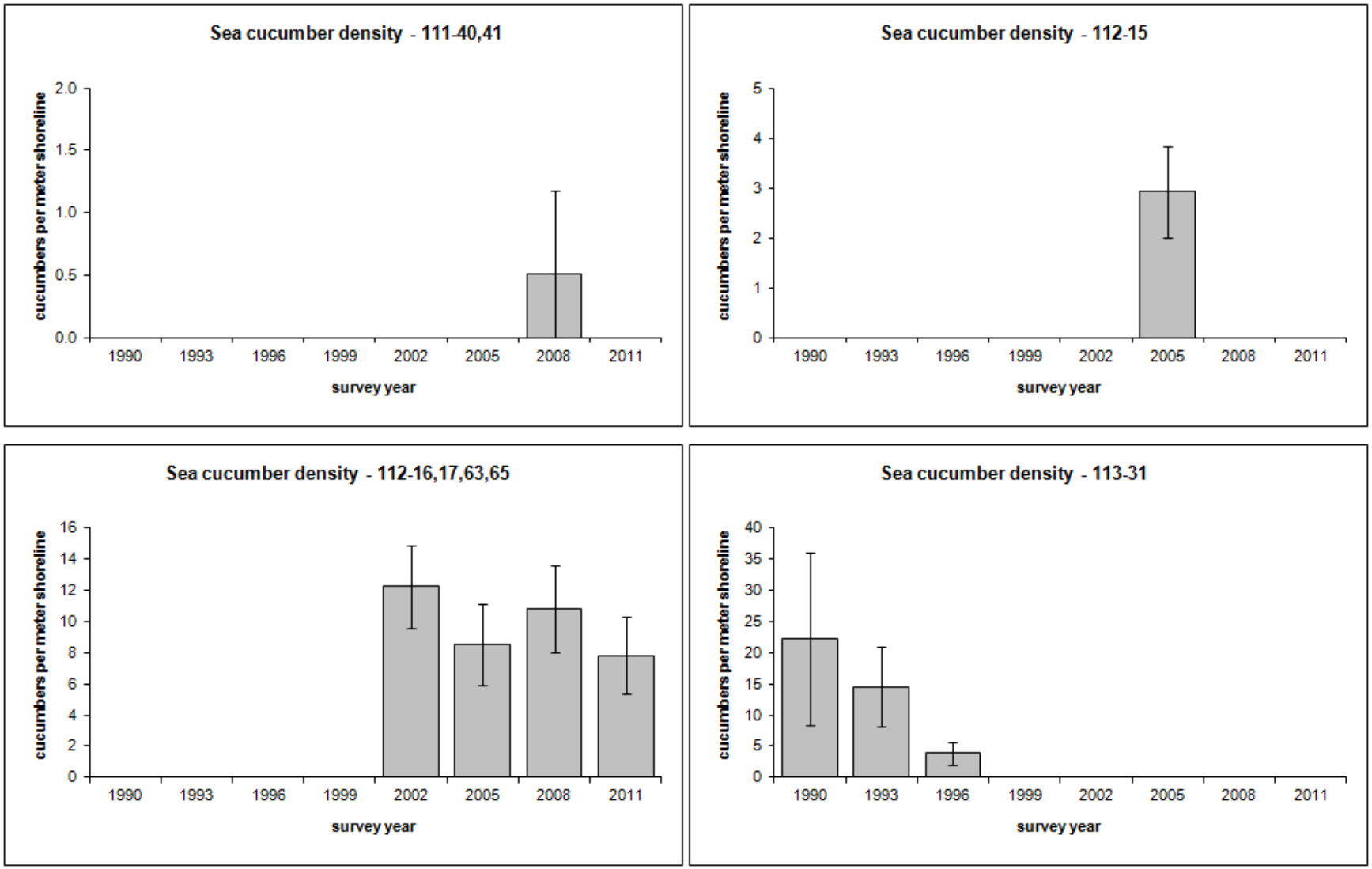


Figure 11.–Average number of sea cucumbers per meter of shoreline from surveys in commercial fishery Subdistricts 111-40,41, Subdistrict 112-15, Subdistricts 112-16,17,63,65, and Subdistrict 113-31, in Southeast Alaska. Error bars represent 90% confidence intervals.

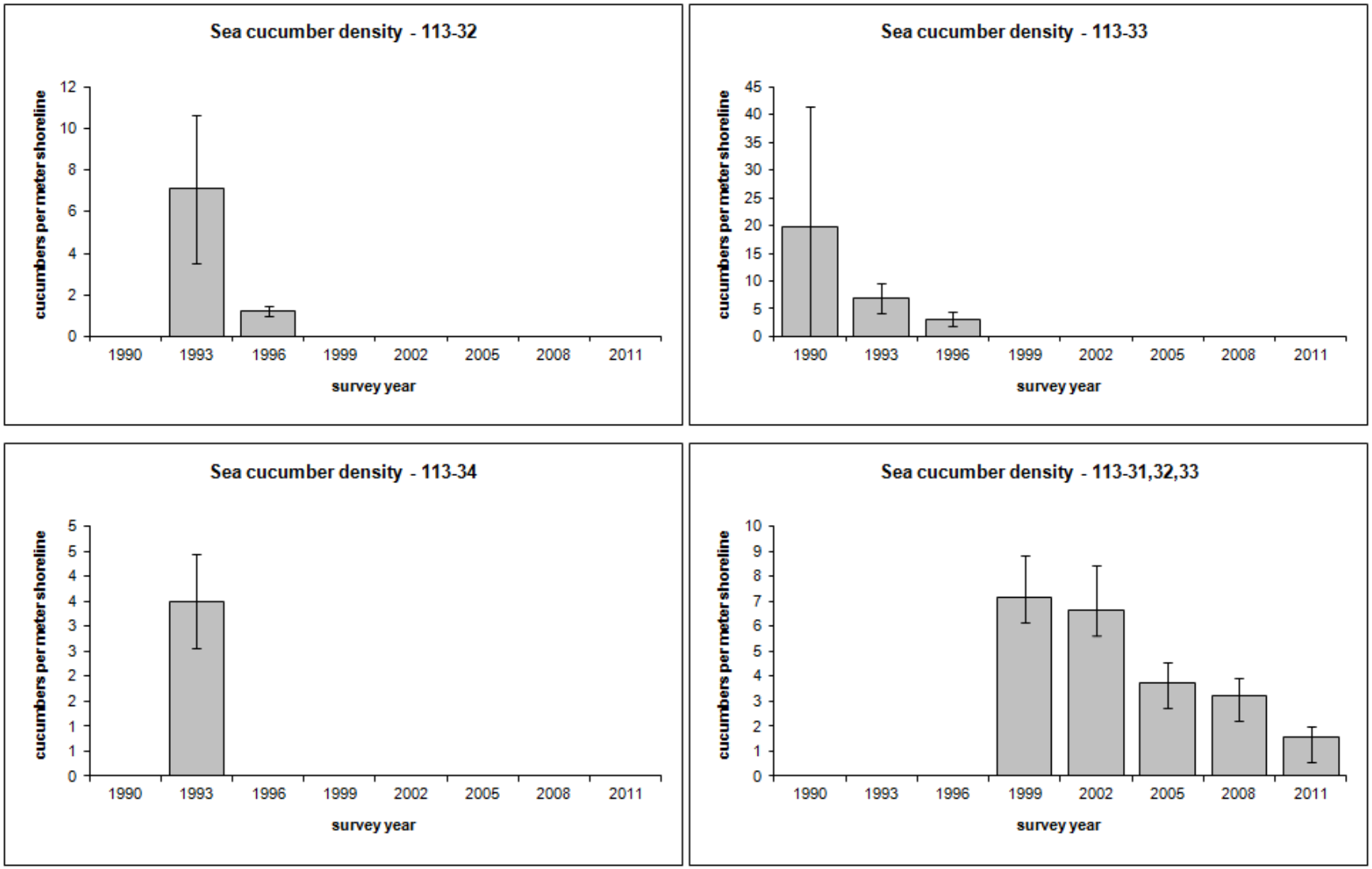


Figure 12.–Average number of sea cucumbers per meter of shoreline from surveys in commercial fishery Subdistrict 113-32, Subdistrict 113-33, Subdistrict 113-34, and Subdistricts 113-31,32,33, in Southeast Alaska. Error bars represent 90% confidence intervals.

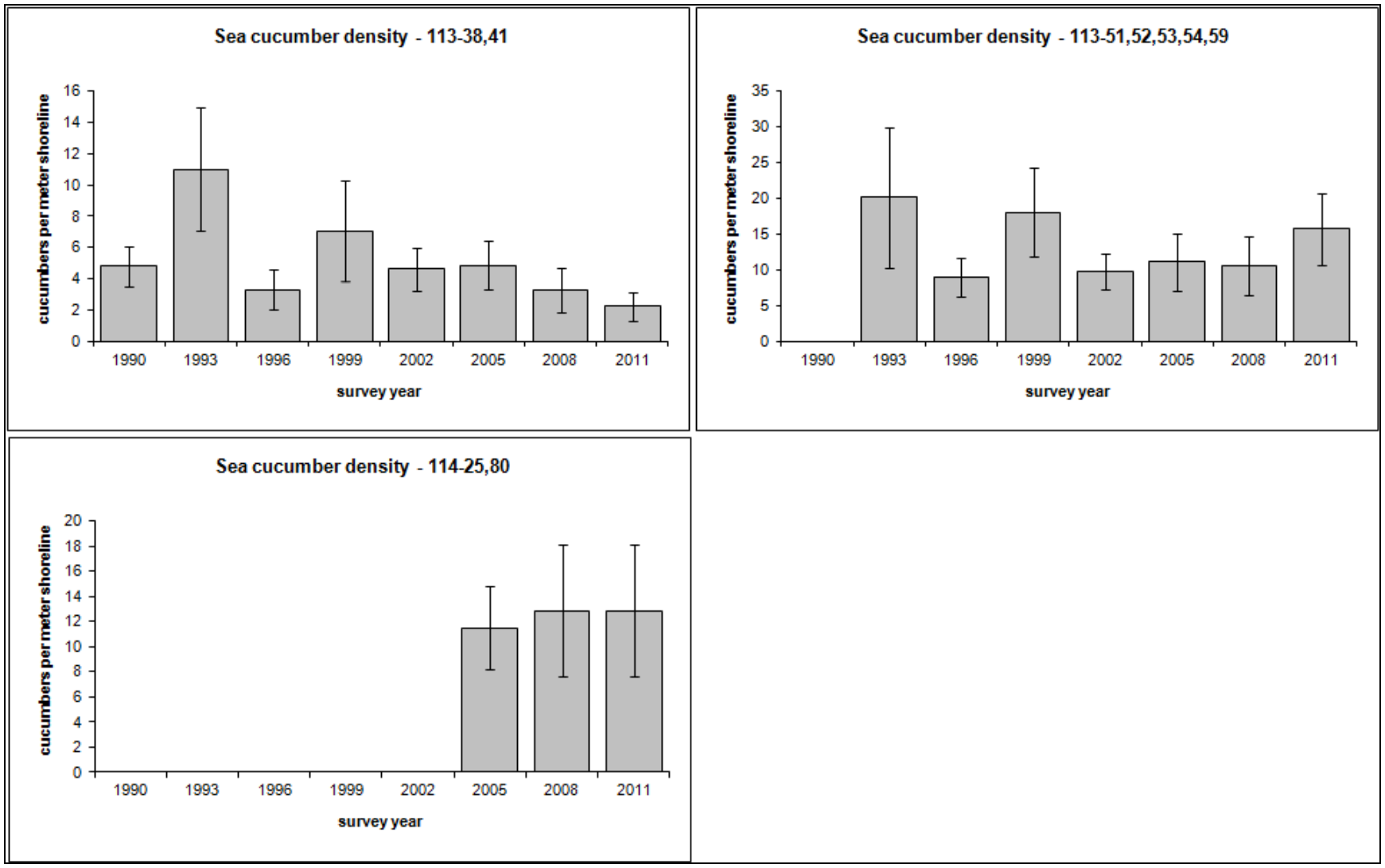


Figure 13.–Average number of sea cucumbers per meter of shoreline from surveys in commercial fishery Subdistricts 113-38,41, Subdistricts 113-51,52,53,54,59, and Subdistrict 114-25,80, in Southeast Alaska. Error bars represent 90% confidence intervals.

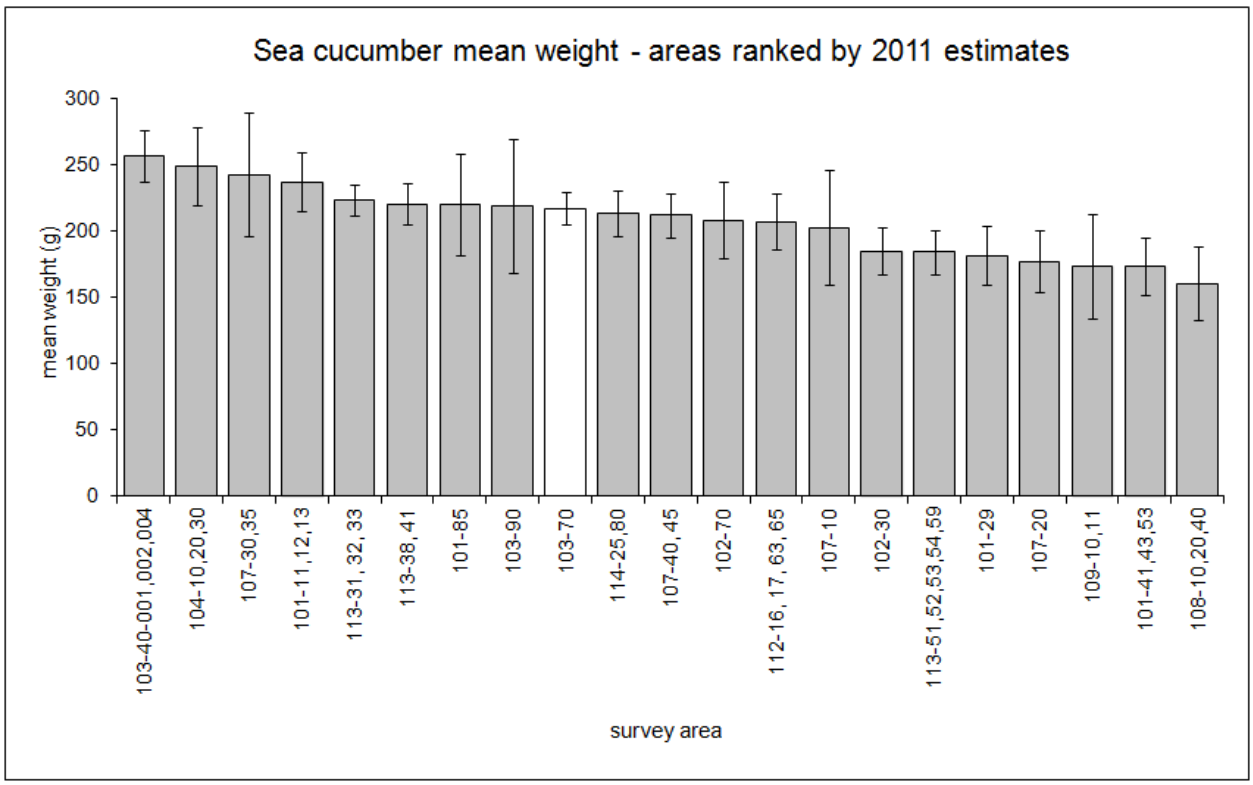


Figure 14.–Estimated sea cucumbers average weight in Southeast Alaska, ranked by survey area using 2011 estimates. Bars with no shading represent values from surveys prior to 2011 as no survey was conducted in 2011 and are shown for comparison. Error bars represent 90% confidence intervals.

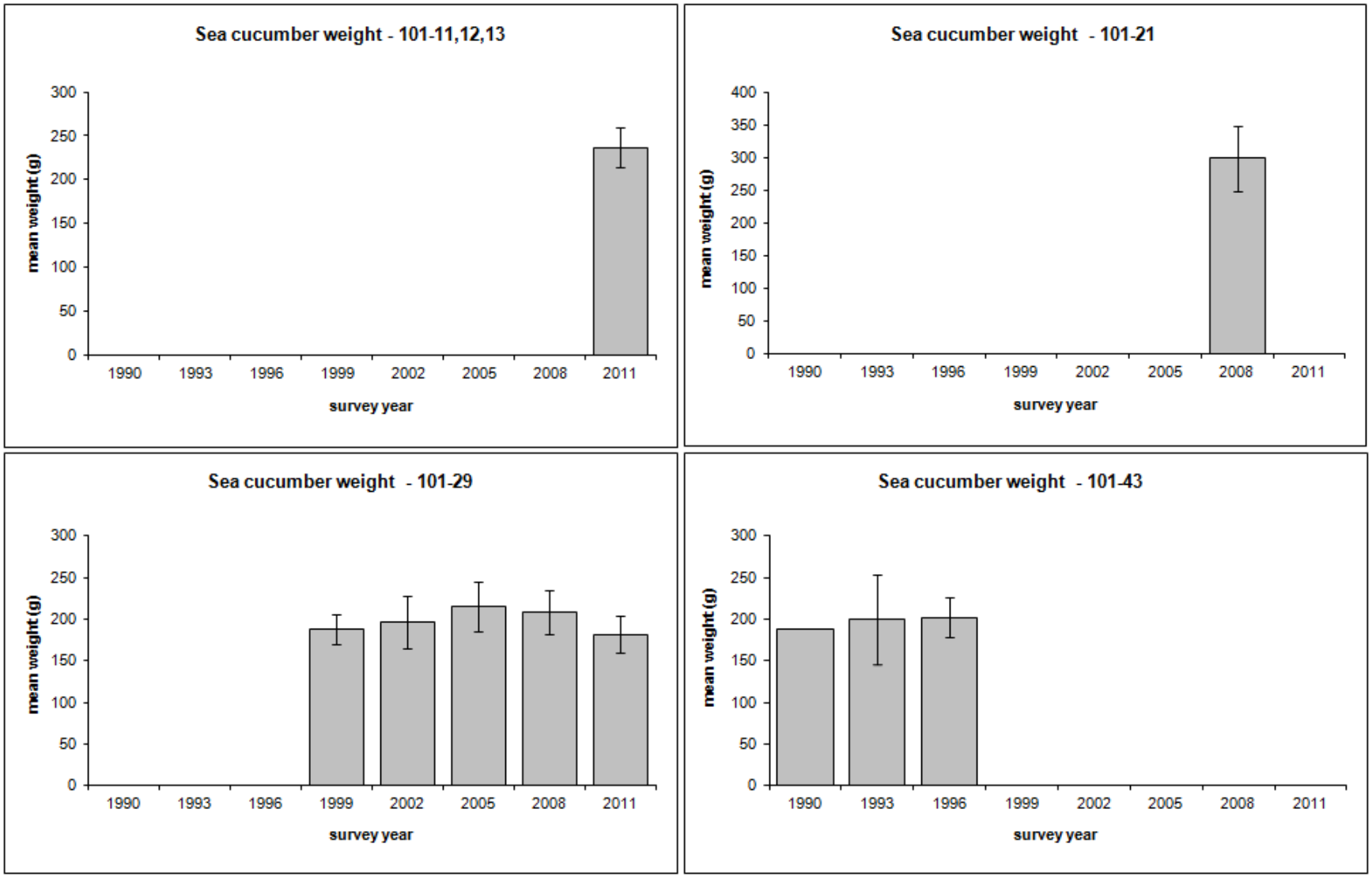


Figure 15.–Average sea cucumber weight (grams) from surveys in commercial fishery Subdistrict 101-11,12,13, Subdistrict 101-21, Subdistrict 101-293, and Subdistricts 101-43 in Southeast Alaska. Error bars represent 90% confidence intervals.

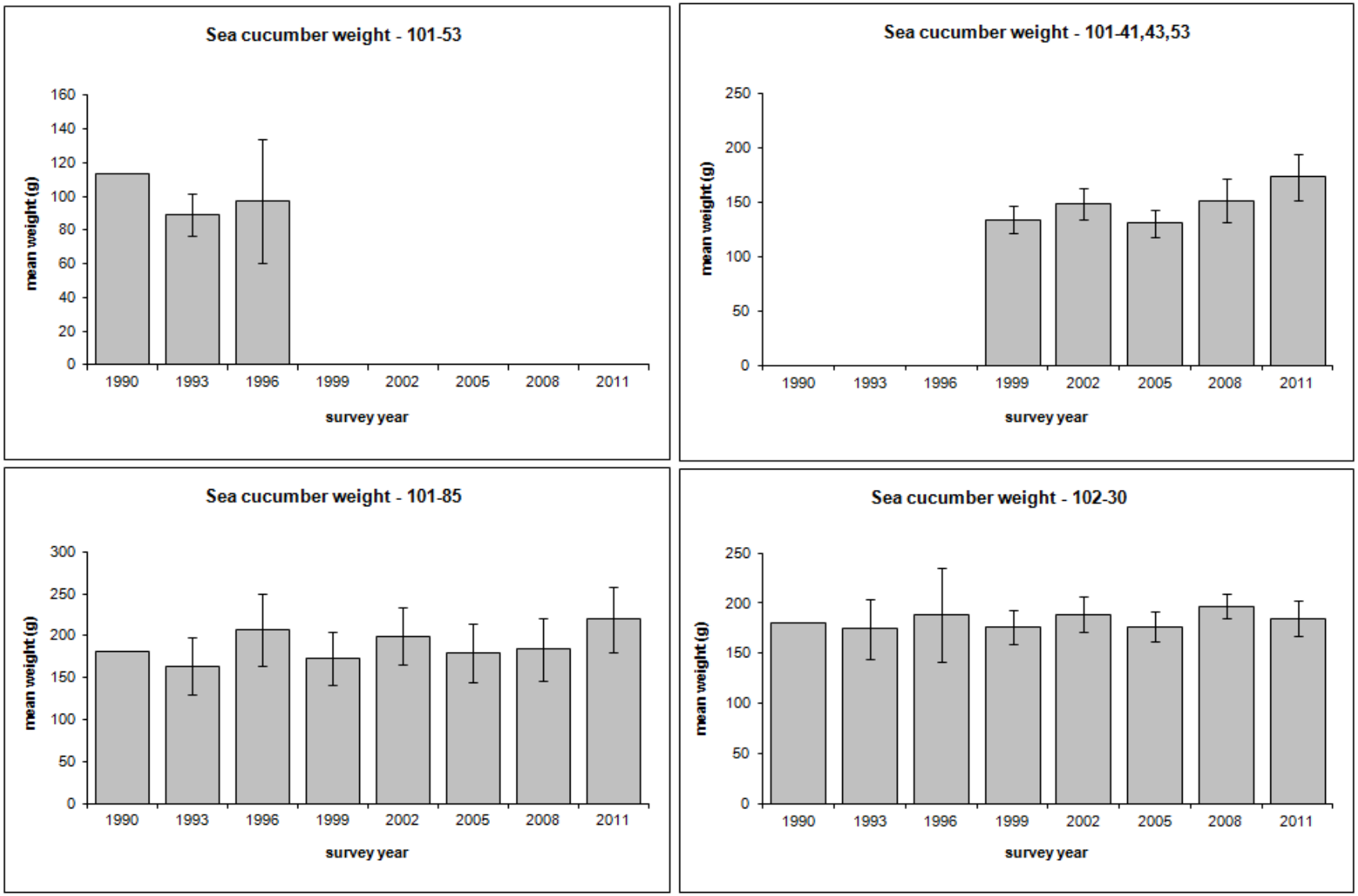


Figure 16.–Average sea cucumber weight (grams) from surveys in commercial fishery Subdistrict 101-53, Subdistricts 101-41,43,53, Subdistricts 101-85, and Subdistrict 102-30 in Southeast Alaska. Error bars represent 90% confidence intervals.

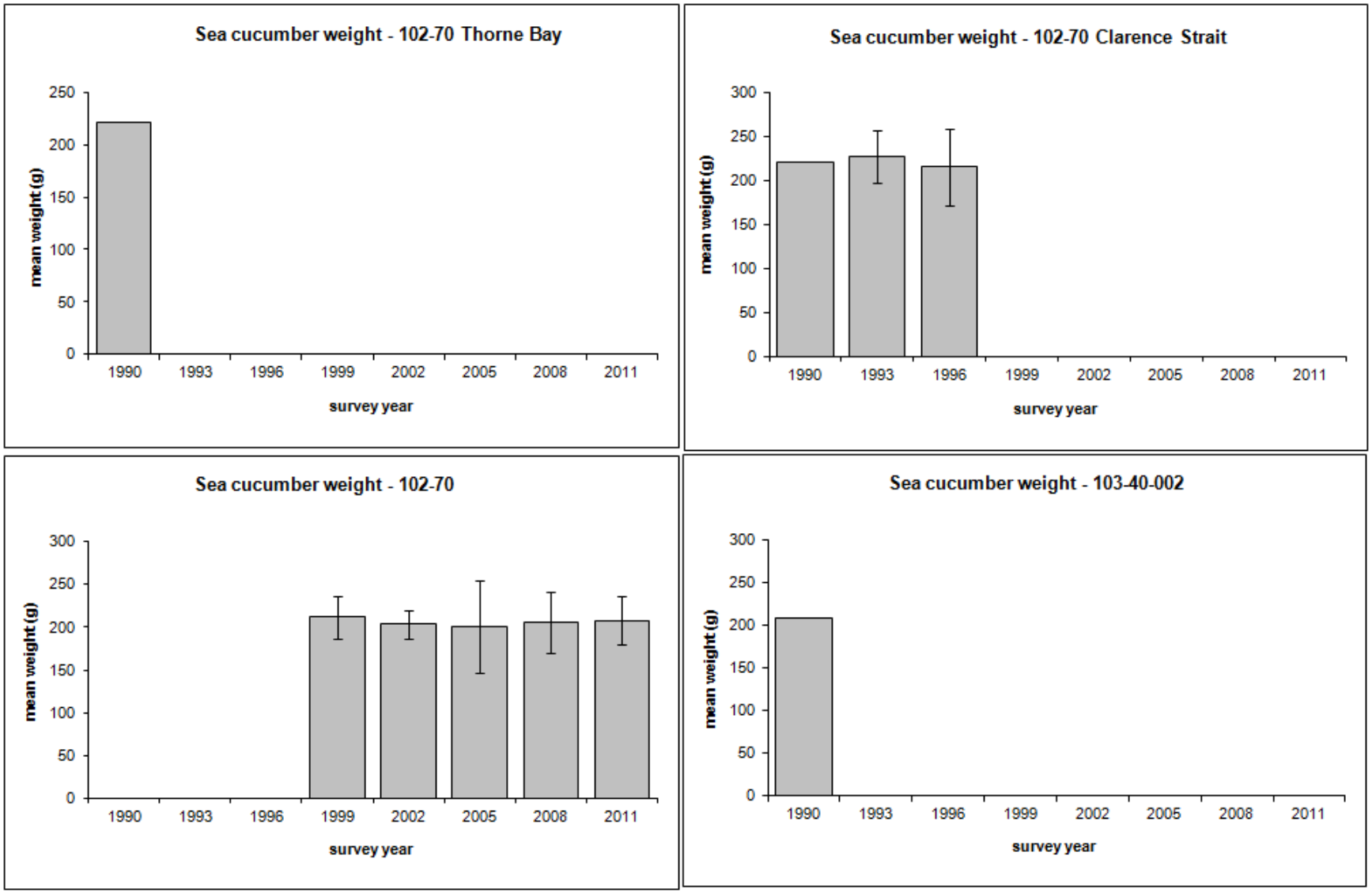


Figure 17.–Average sea cucumber weight (grams) from surveys in commercial fishery Subdistrict 102-70 (Thorne Bay), Subdistrict 102-70 (Clarence Strait), Subdistrict 102-70, and Subdistrict 103-40-002, in Southeast Alaska. Error bars represent 90% confidence intervals.

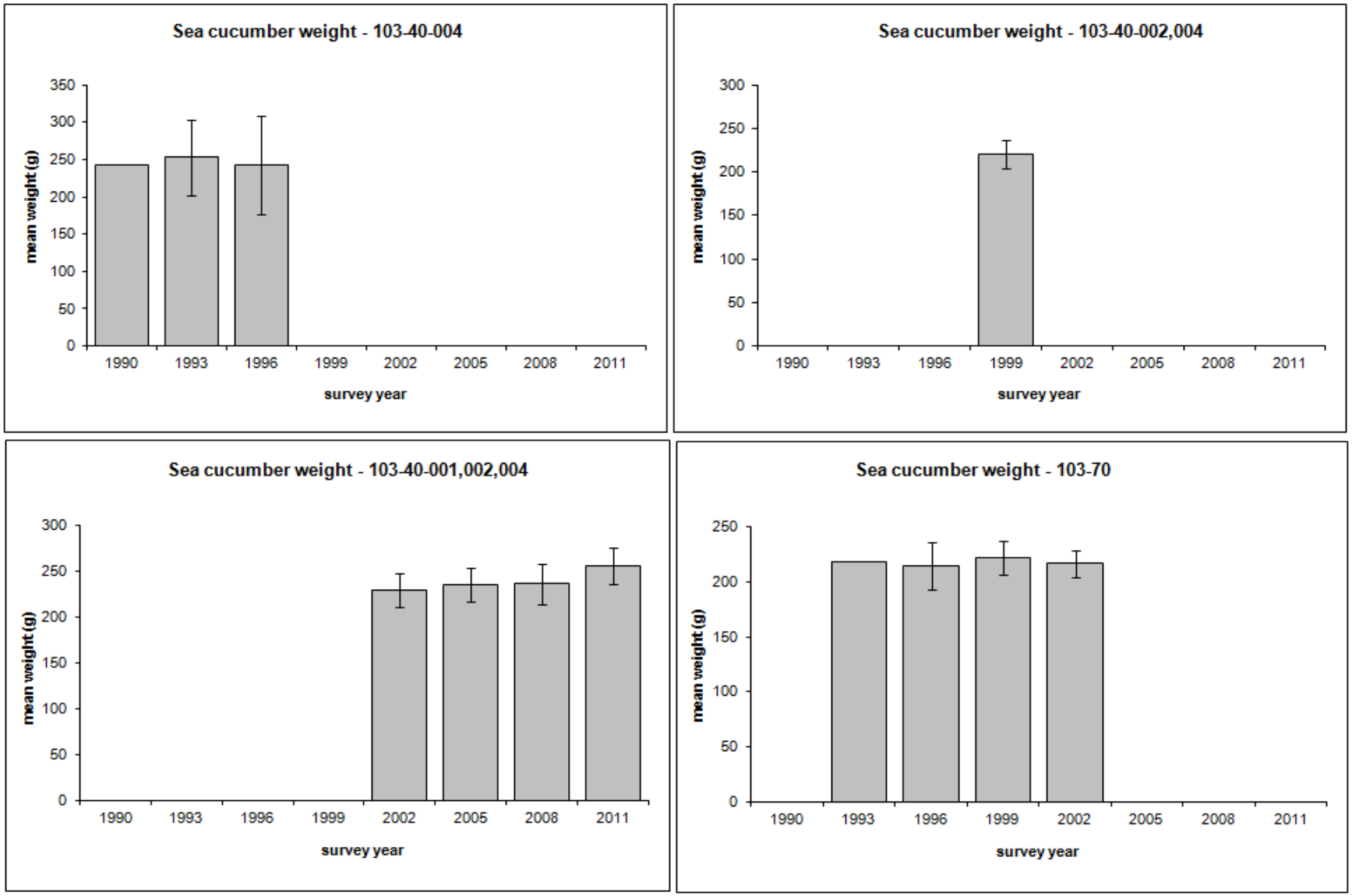


Figure 18.–Average sea cucumber weight from surveys in commercial fishery Subdistrict 103-40-004, Subdistrict 103-40-002,004, Subdistrict 103-40-001,002,004, and Subdistrict 103-70, in Southeast Alaska. Error bars represent 90% confidence intervals.

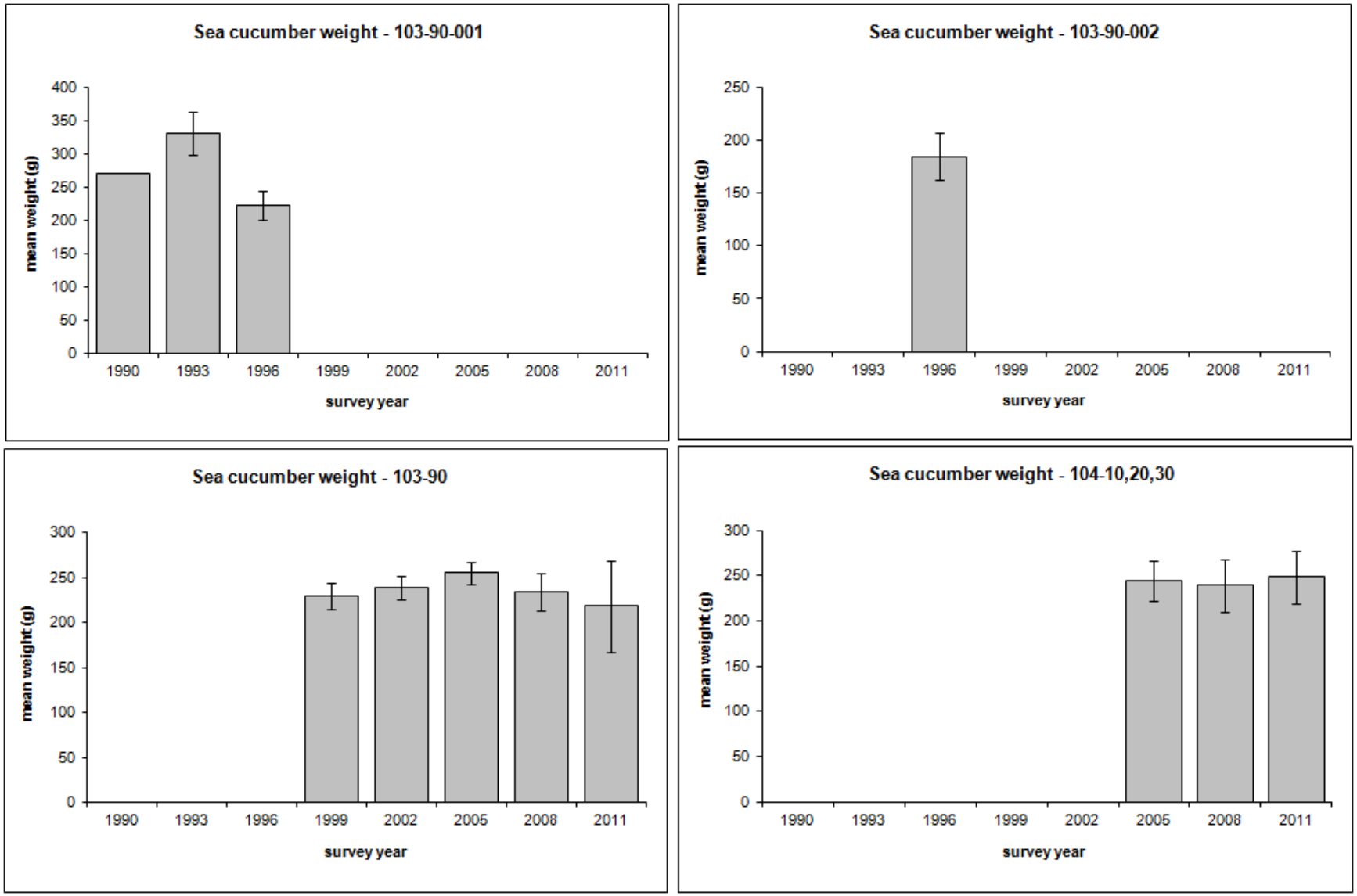


Figure 19.–Average sea cucumber weight (grams) from surveys in commercial fishery Subdistrict 103-90-001, and Subdistrict 103-90-002, Subdistrict 103-90, and Subdistricts 104-10,20,30, in Southeast Alaska. Error bars represent 90% confidence intervals.

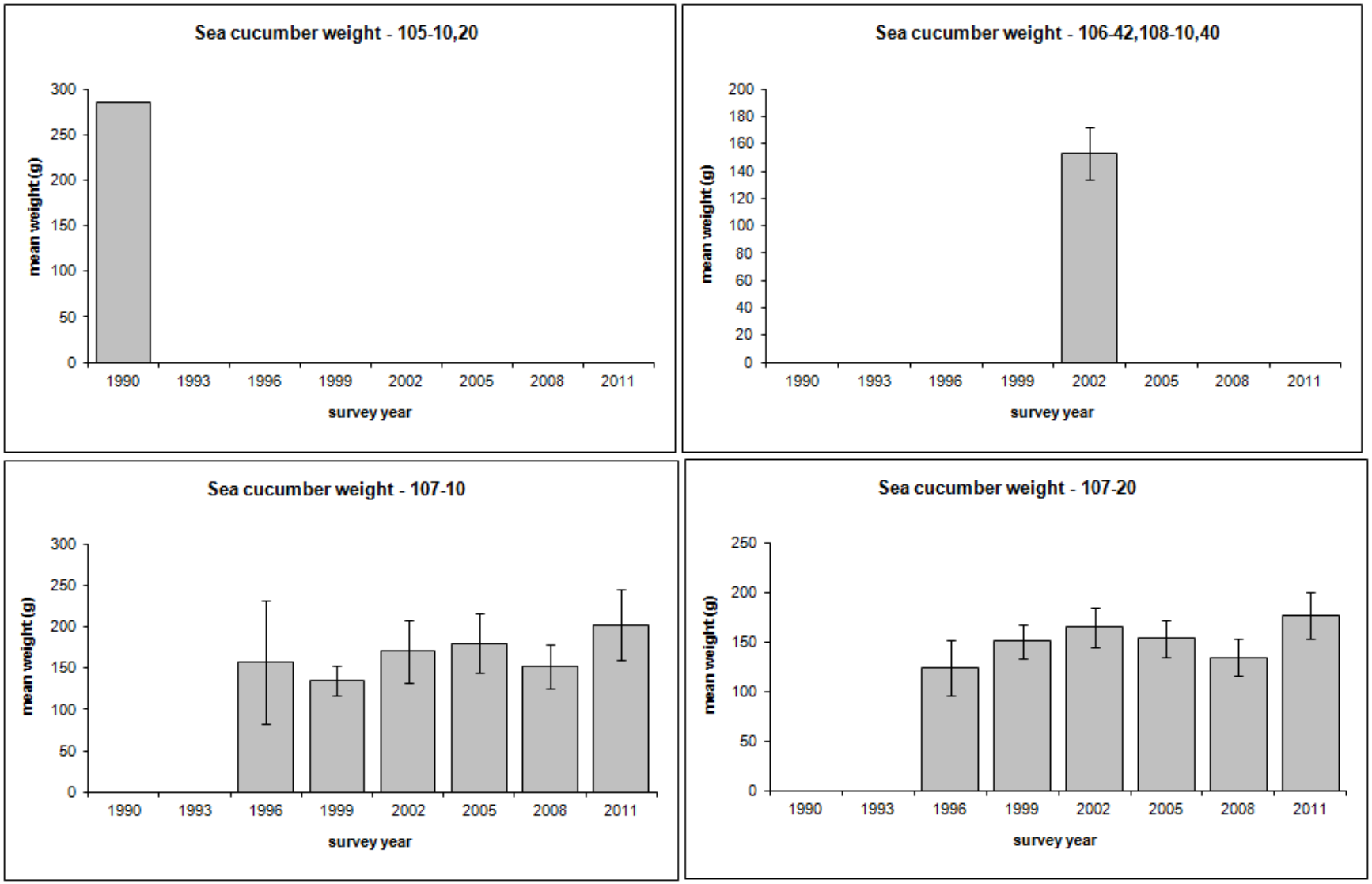


Figure 20.–Average sea cucumber weight (grams) from surveys in commercial fishery Subdistricts 105-10,20, Subdistricts 106-42,108-10,40, Subdistrict 107-10, and Subdistrict 107-20, in Southeast Alaska. Error bars represent 90% confidence intervals.

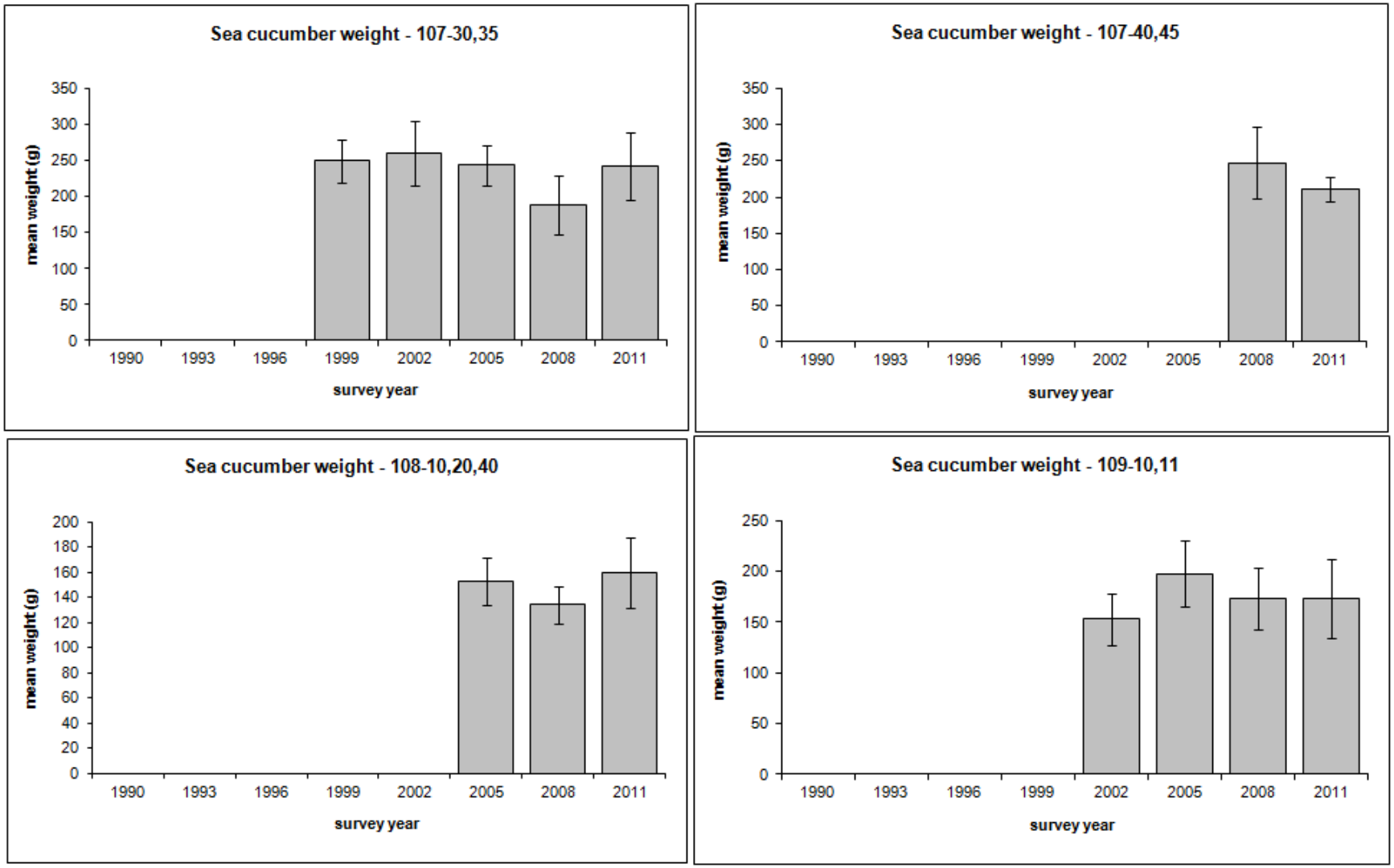


Figure 21.–Average sea cucumber weight (grams) from surveys in commercial fishery Subdistricts 107-30,35, Subdistricts 107-40,45, Subdistricts 108-10,20,40, and Subdistricts 109-10,11, in Southeast Alaska. Error bars represent 90% confidence intervals.

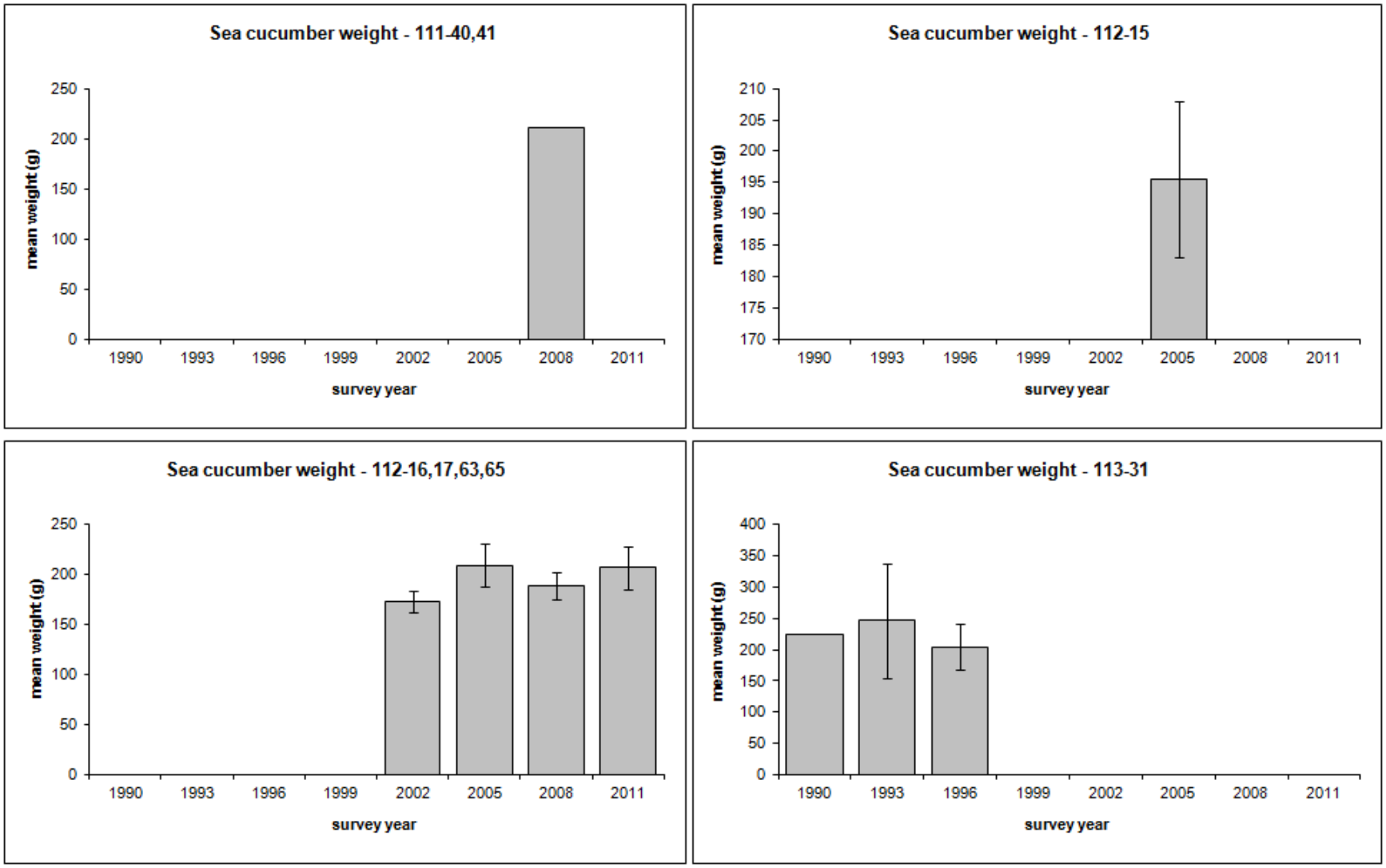


Figure 22.–Average sea cucumber weight (grams) from surveys in commercial fishery Subdistricts 111-40,41, Subdistrict 112-15, Subdistricts 112-16,17,63,65, and Subdistrict 113-31, in Southeast Alaska. Error bars represent 90% confidence intervals.

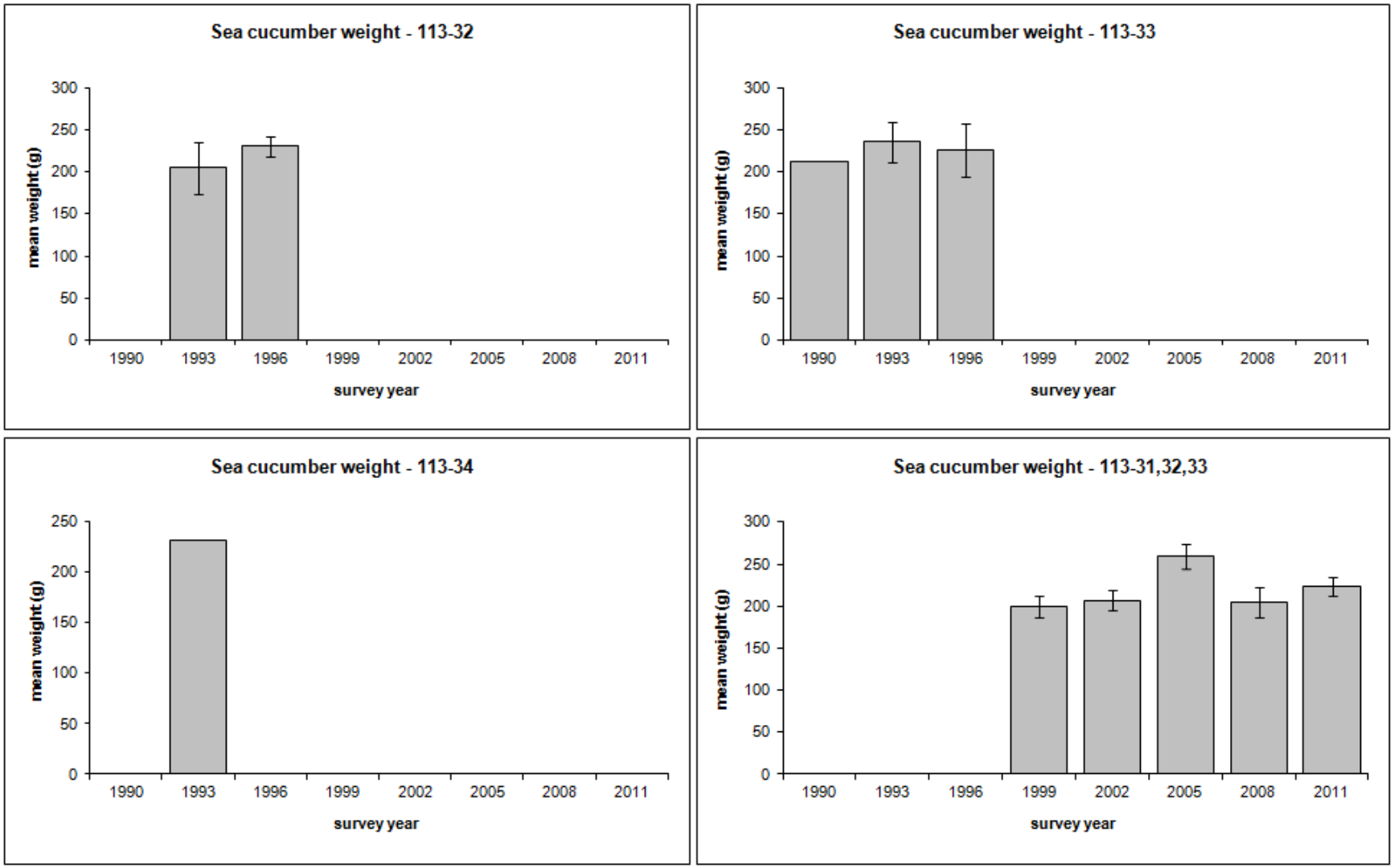


Figure 23.–Average sea cucumber weight (grams) from surveys in commercial fishery Subdistrict 113-32, Subdistrict 113-33, Subdistrict 113-34, and Subdistricts 113-31,32,33, in Southeast Alaska. Error bars represent 90% confidence intervals.

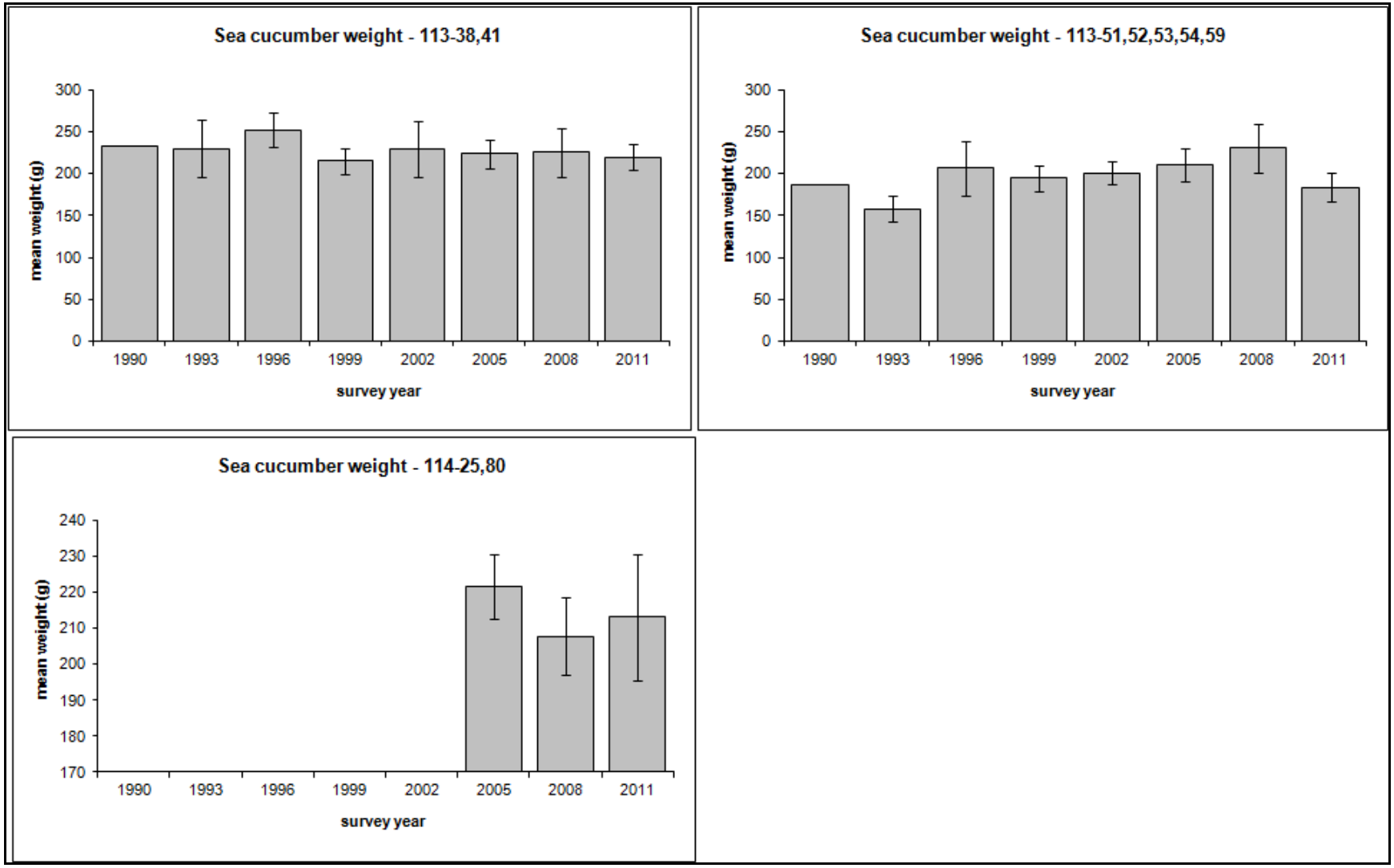


Figure 24.–Average sea cucumber weight (grams) from surveys in commercial fishery Subdistricts 113-38,41, Subdistricts 113-51,52,53,54,59, and Subdistricts 114-25,80, in Southeast Alaska. Error bars represent 90% confidence intervals.

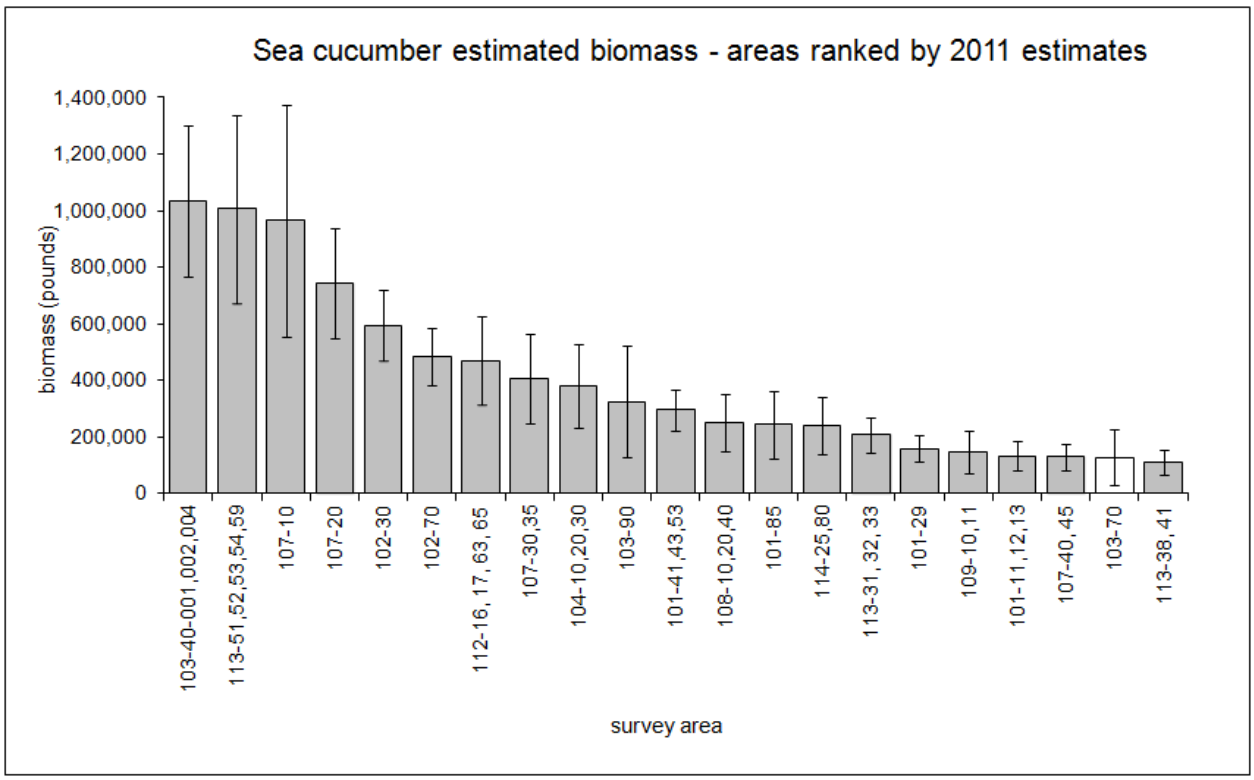


Figure 25.–Estimated sea cucumber biomass (ranked using 2011 results) in Southeast Alaska. Bars with no shading represent values from surveys prior to 2011, as no survey was conducted in 2011, and are shown for comparison. Error bars represent 90% confidence intervals.

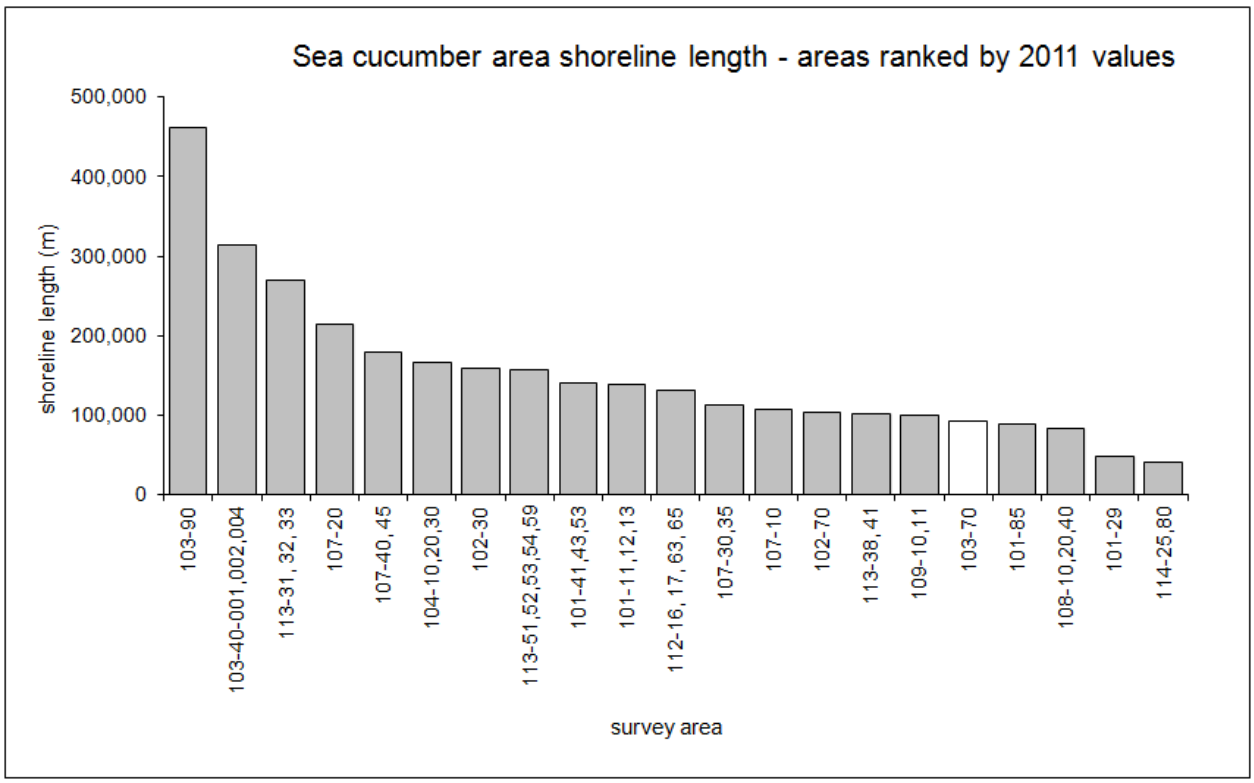


Figure 26.–Measurements of estimated sea cucumber habitat shoreline in Southeast Alaska.

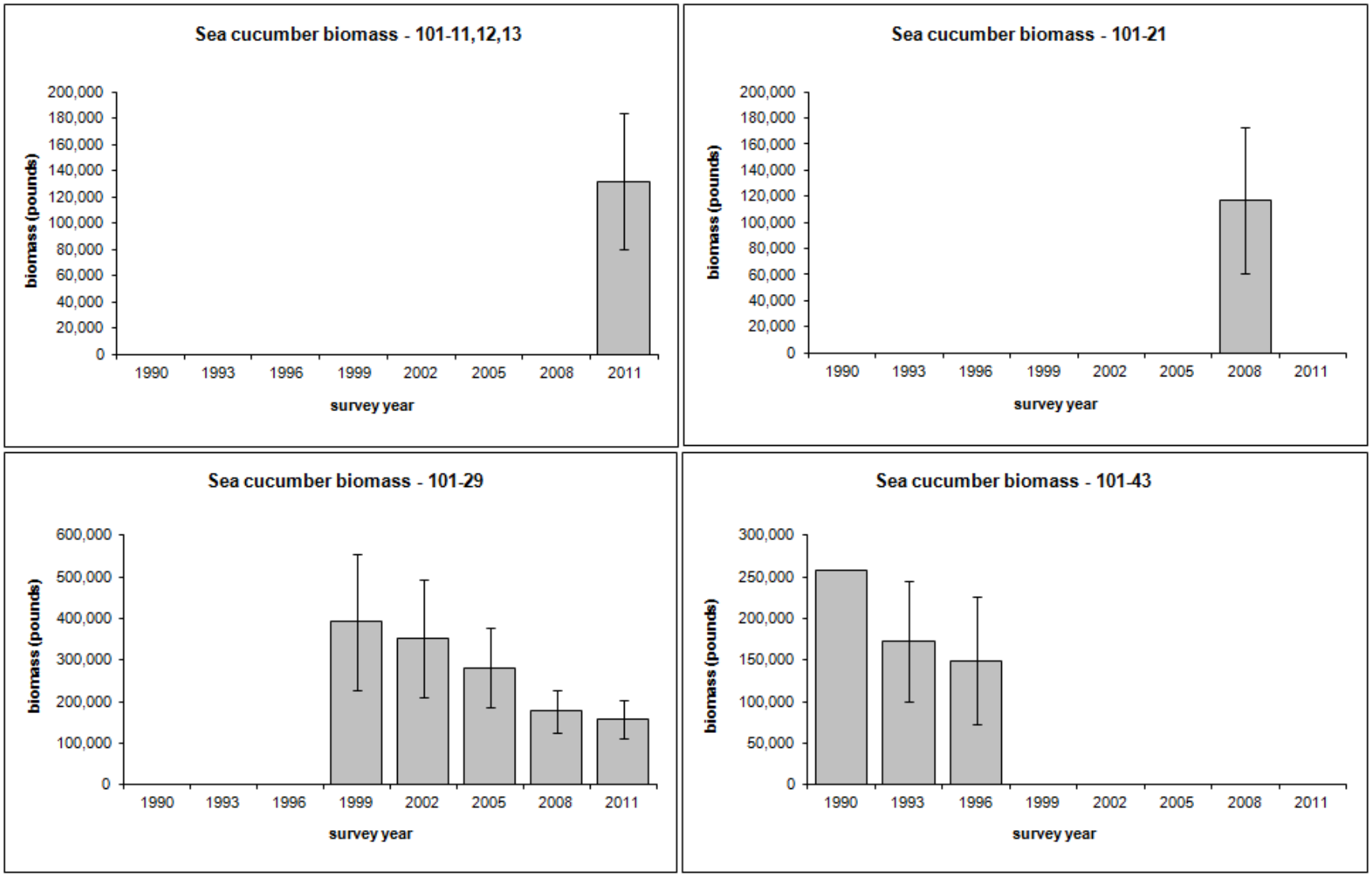


Figure 27.–Total sea cucumber biomass (pounds) from surveys in commercial fishery Subdistricts 101-11,12,13, Subdistrict 101-21, Subdistrict 101-29, and Subdistrict 101-43, in Southeast Alaska. Error bars represent 90% confidence intervals.

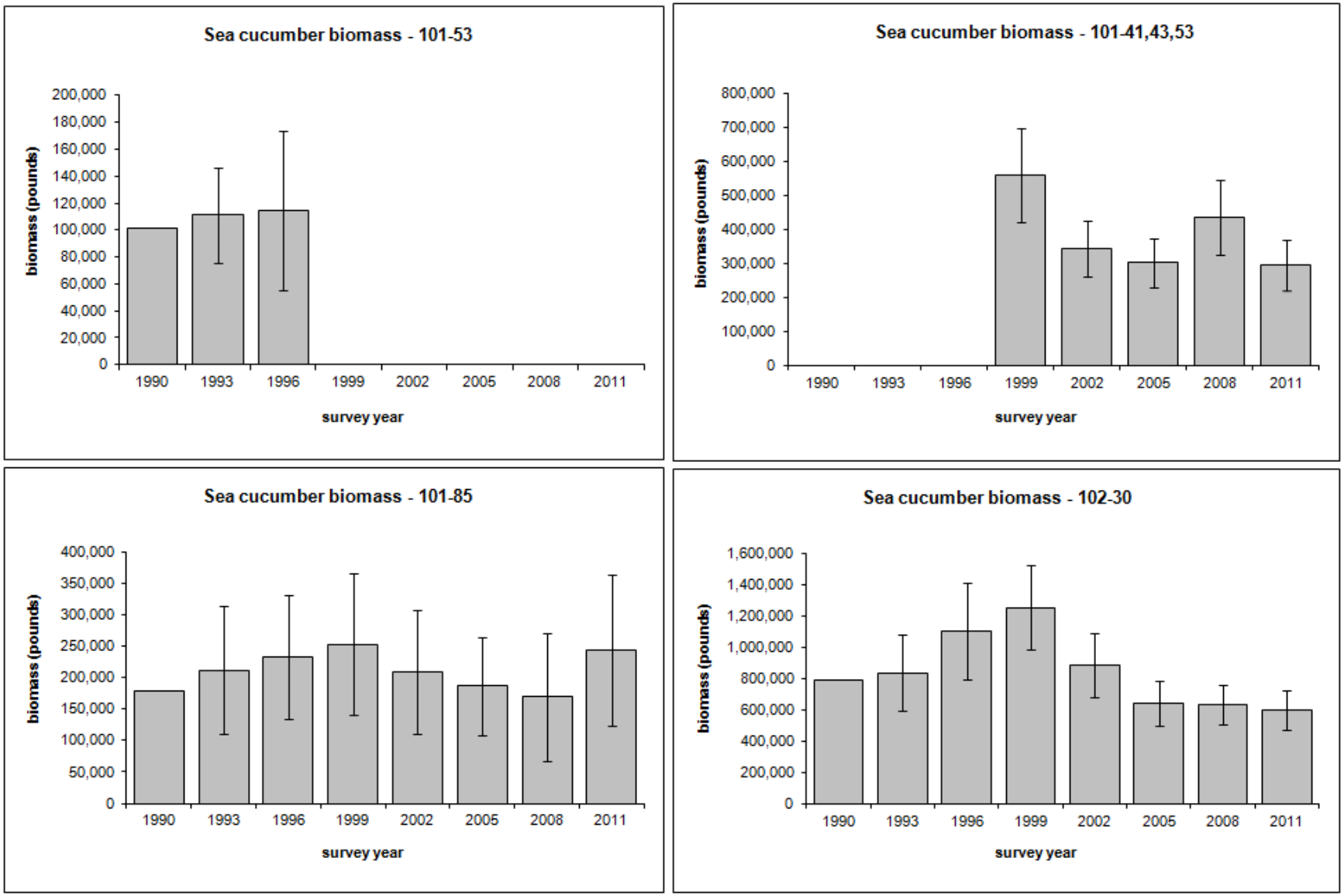


Figure 28.–Total sea cucumber biomass (pounds) from surveys in commercial fishery Subdistrict 101-53, Subdistricts 101-41,43,53, Subdistrict 101-85, and Subdistrict 102-30, in Southeast Alaska. Error bars represent 90% confidence intervals.

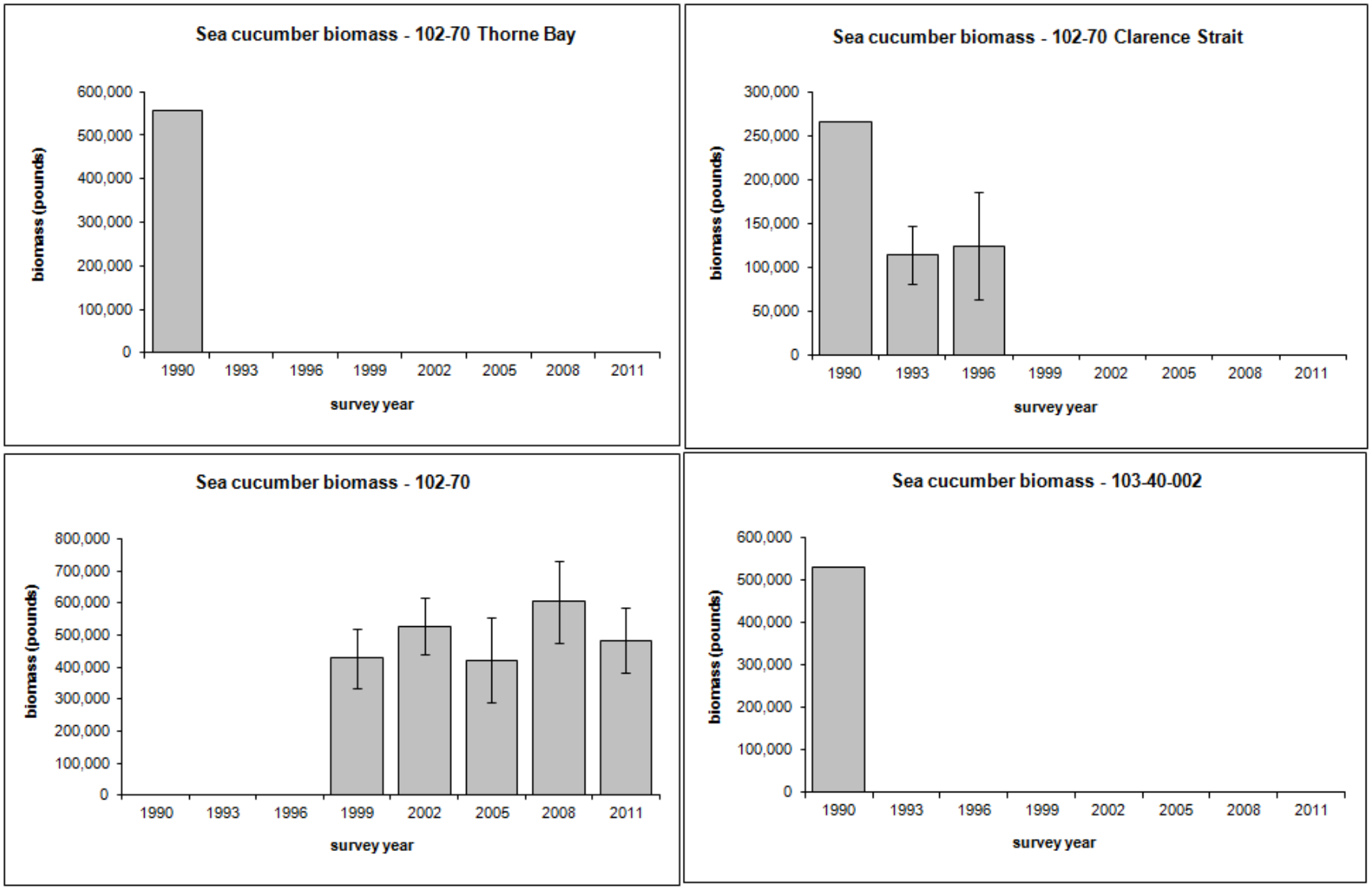


Figure 29.–Total sea cucumber biomass (pounds) from surveys in commercial fishery Subdistrict 102-70 (Thorne Bay), Subdistrict 102-70 (Clarence Strait), Subdistrict 102-70, and Subdistrict 103-40-002, in Southeast Alaska. Error bars represent 90% confidence intervals.

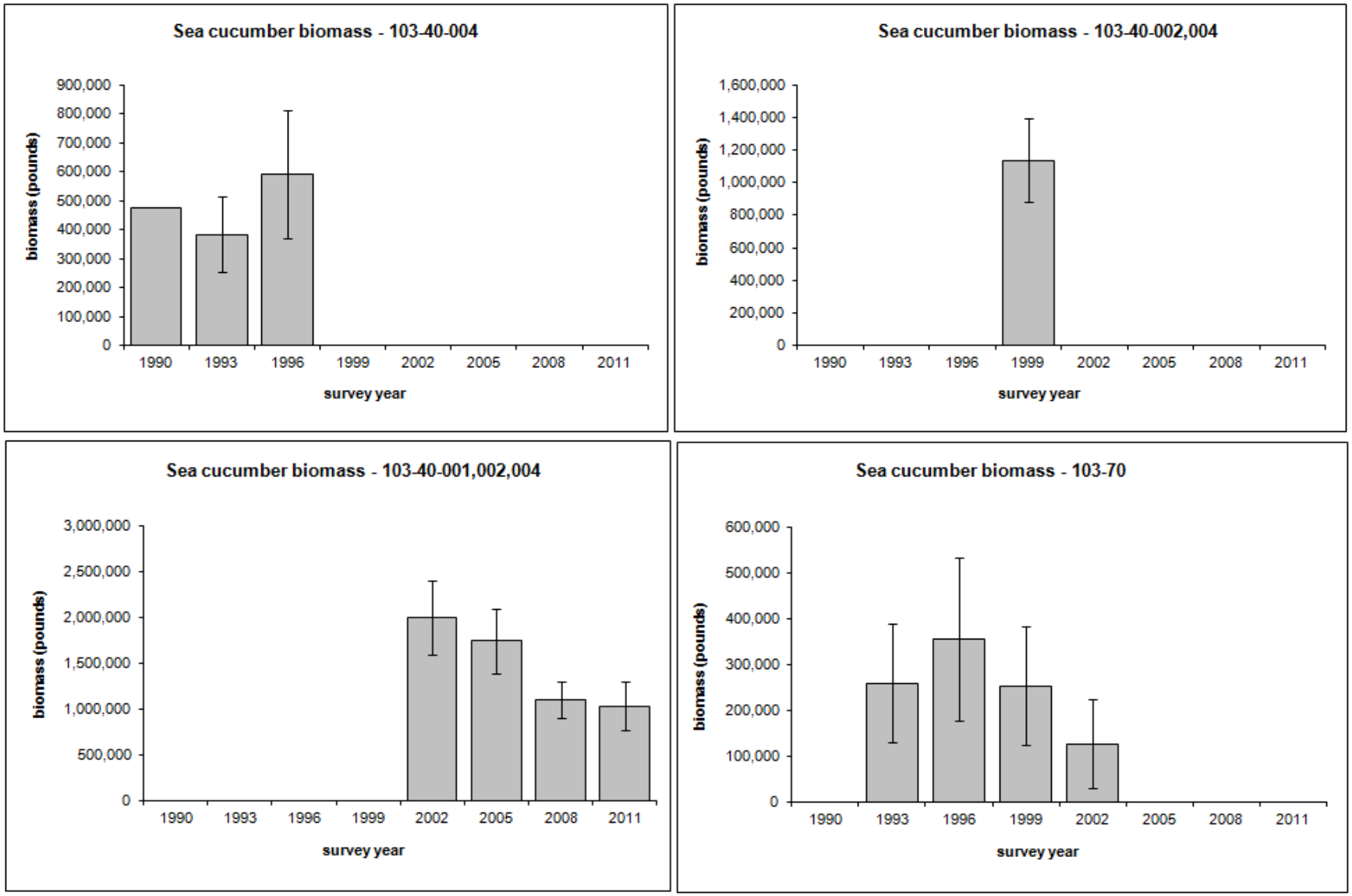


Figure 30.–Total sea cucumber biomass (pounds) from surveys in commercial fishery Subdistrict 103-40-004, Subdistrict 103-40-002,004, Subdistrict 103-40-001,002,004, and Subdistrict 103-70, in Southeast Alaska. Error bars represent 90% confidence intervals.

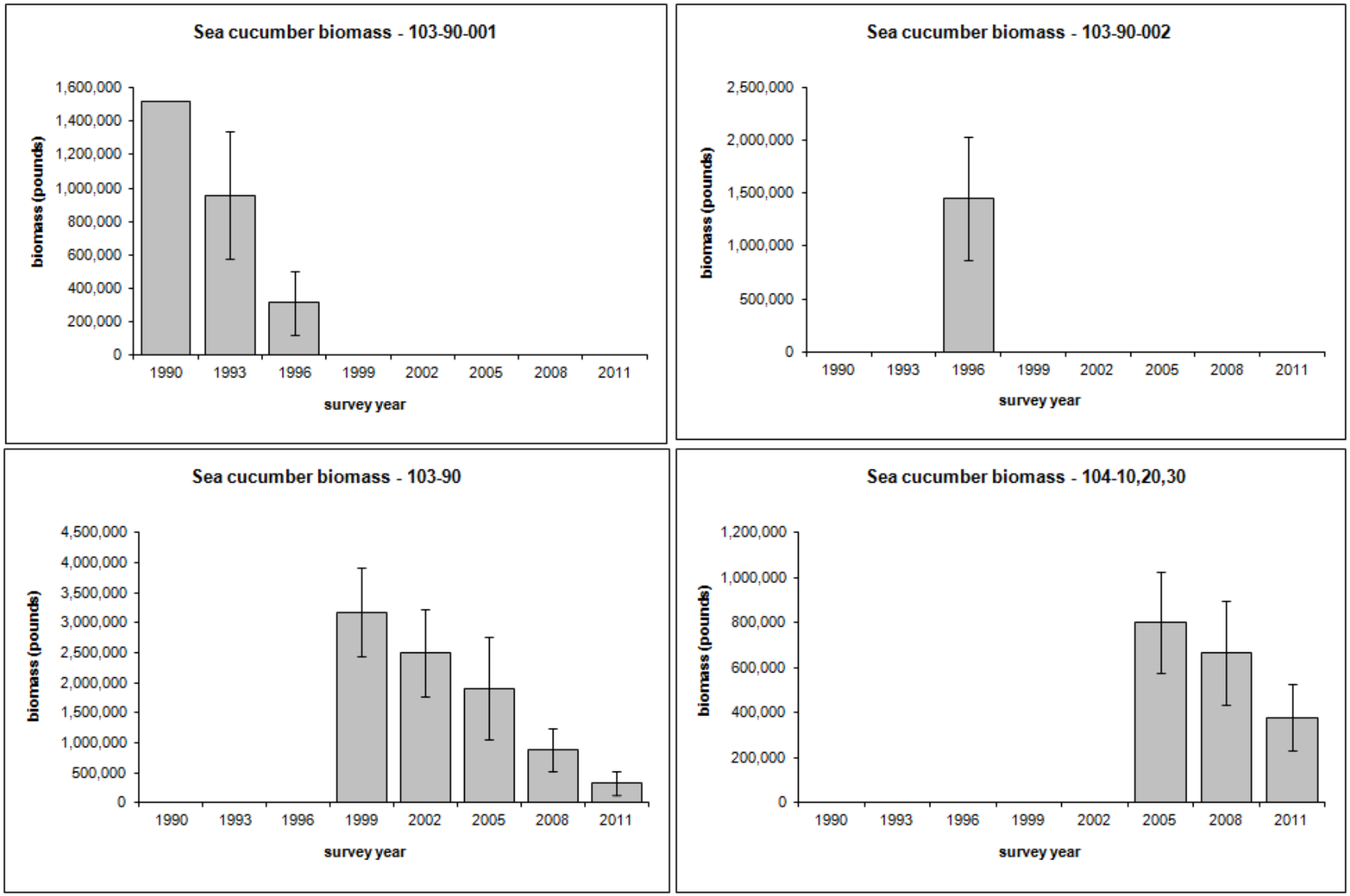


Figure 31.–Total sea cucumber biomass (pounds) from surveys in commercial fishery Subdistrict 103-90-001, Subdistrict 103-90-002, Subdistrict 103-90, and Subdistricts 104-10,20,30, in Southeast Alaska. Error bars represent 90% confidence intervals.

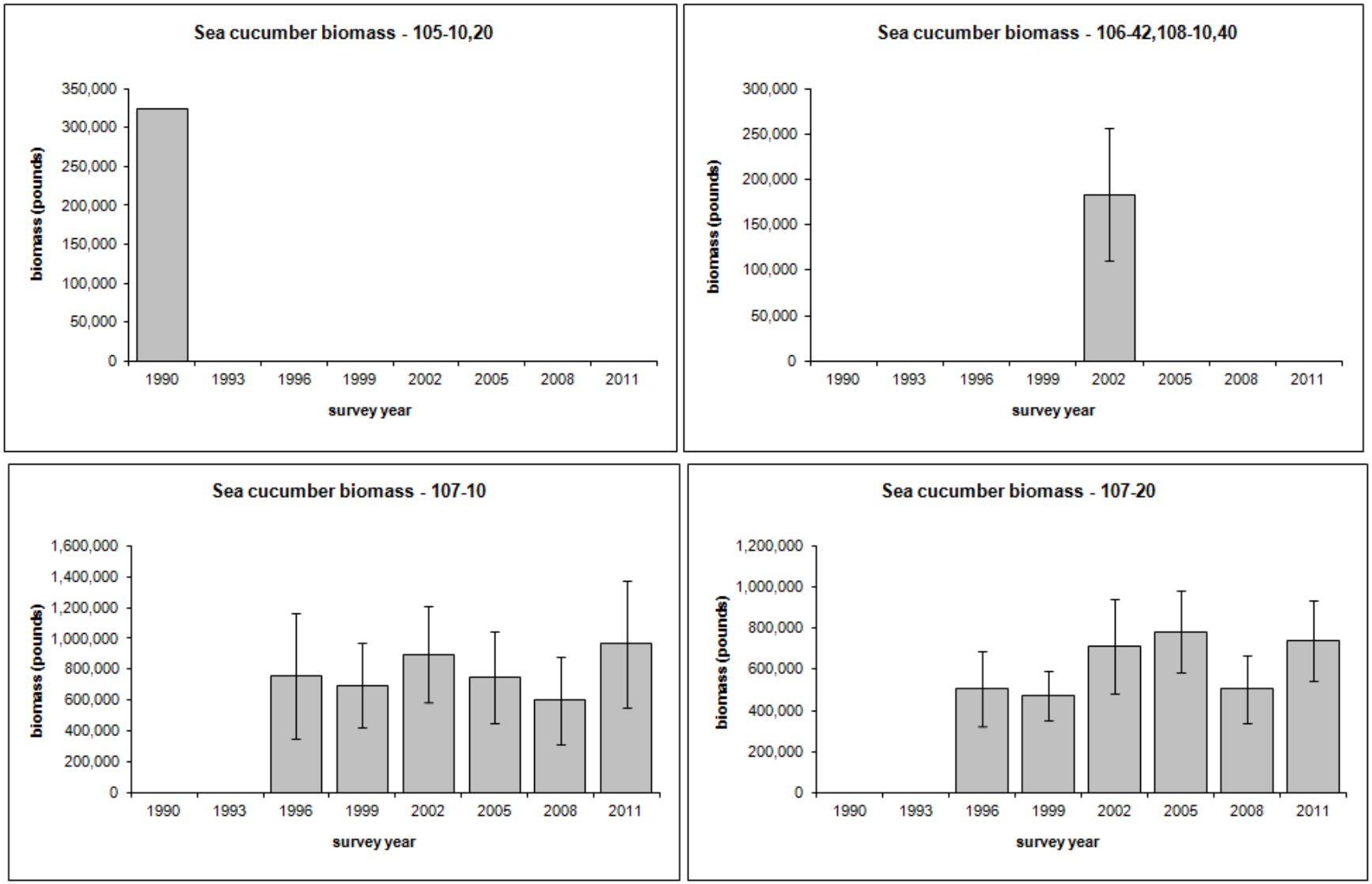


Figure 32.–Total sea cucumber biomass (pounds) from surveys in commercial fishery Subdistricts 105-10,20, Subdistricts 106-42,108-10,40, Subdistrict 107-10, and Subdistrict 107-20, in Southeast Alaska. Error bars represent 90% confidence intervals.

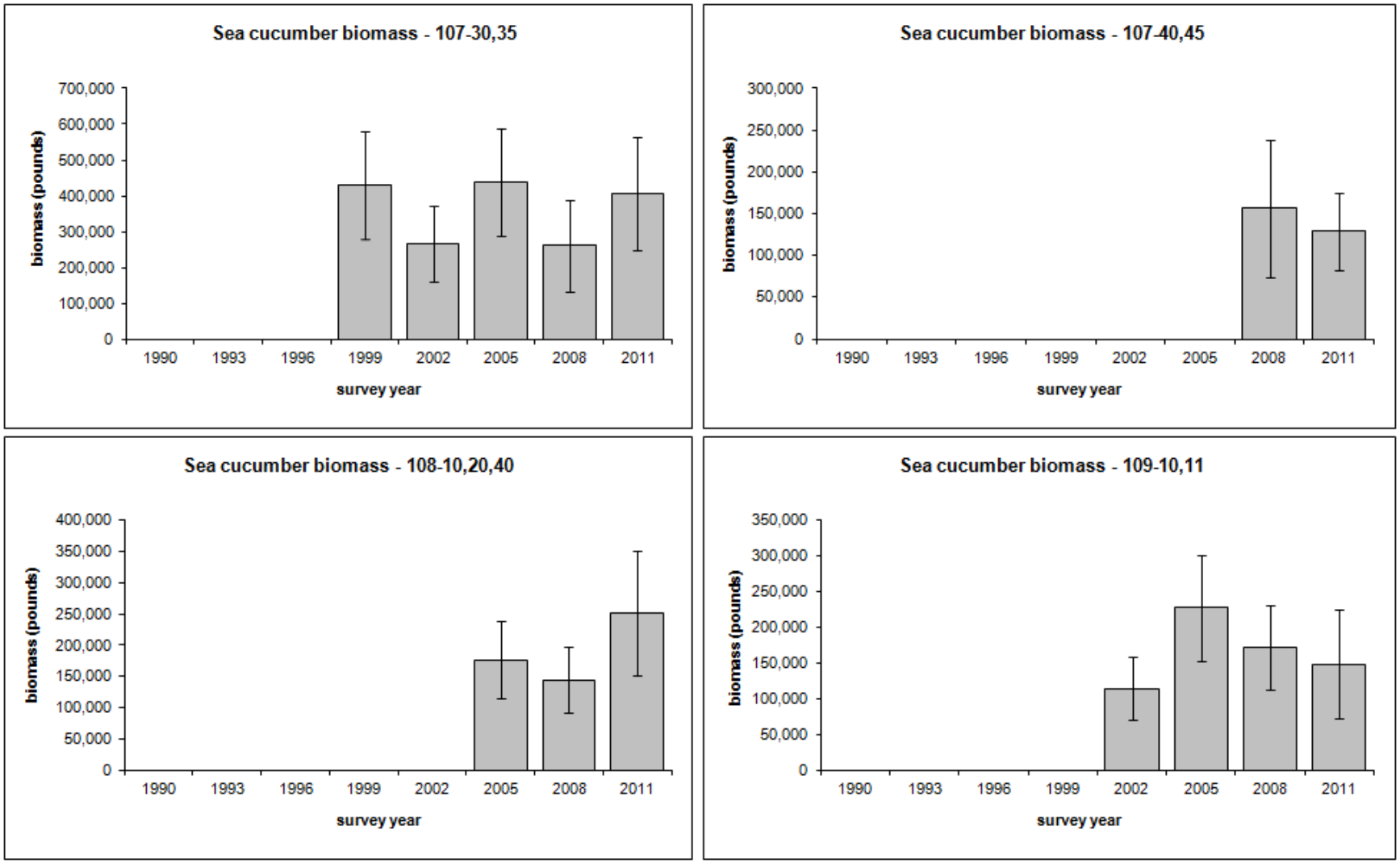


Figure 33.–Total sea cucumber biomass (pounds) from surveys in commercial fishery Subdistricts 107-30,35, Subdistricts 107-40,45, Subdistricts 108-10,20,40, and Subdistricts 109-10,11, in Southeast Alaska. Error bars represent 90% confidence intervals.

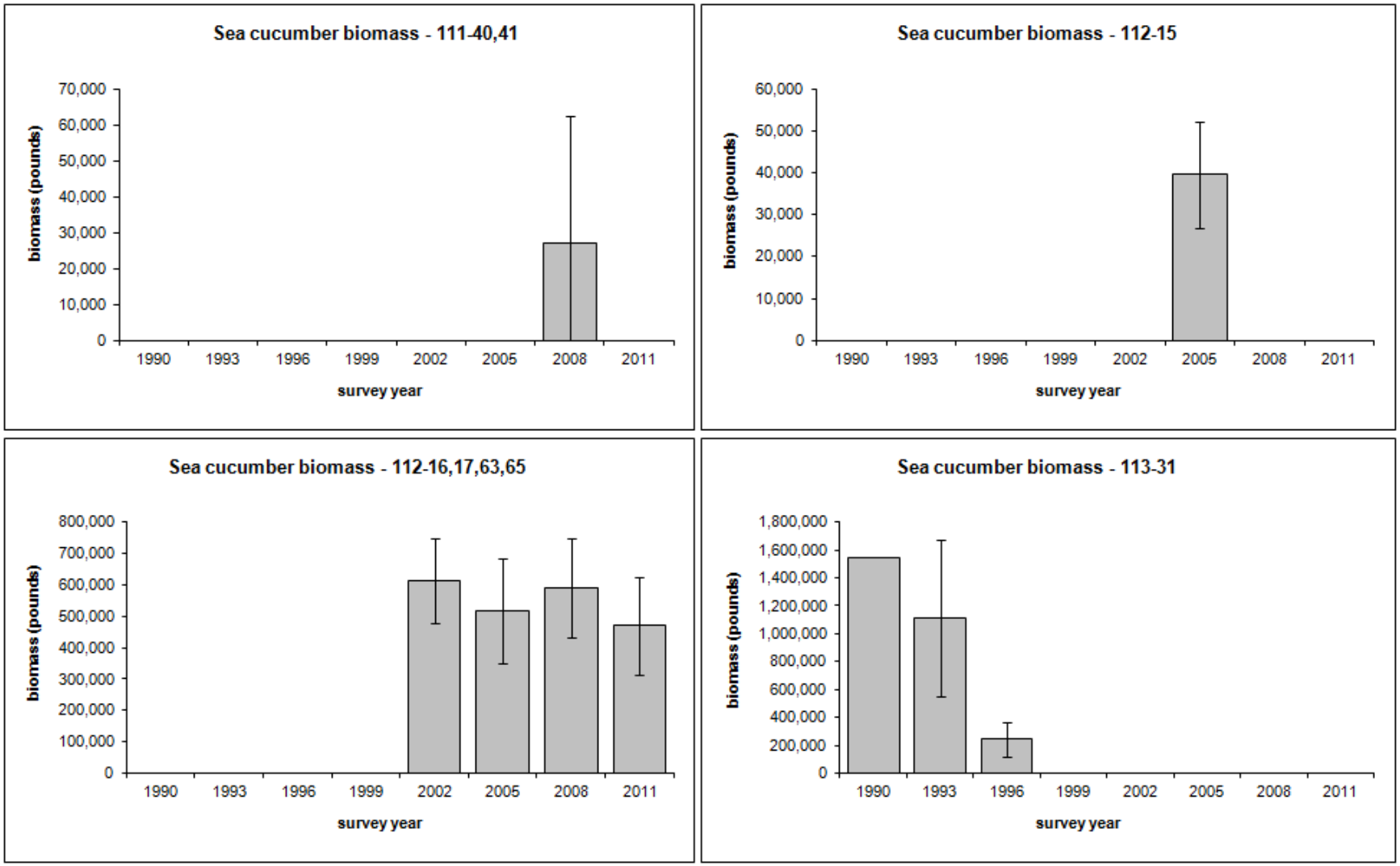


Figure 34.–Total sea cucumber biomass (pounds) from surveys in commercial fishery Subdistricts 111-40,41, Subdistrict 112-15, Subdistricts 112-16,17,63,65, and Subdistrict 113-31, in Southeast Alaska. Error bars represent 90% confidence intervals.

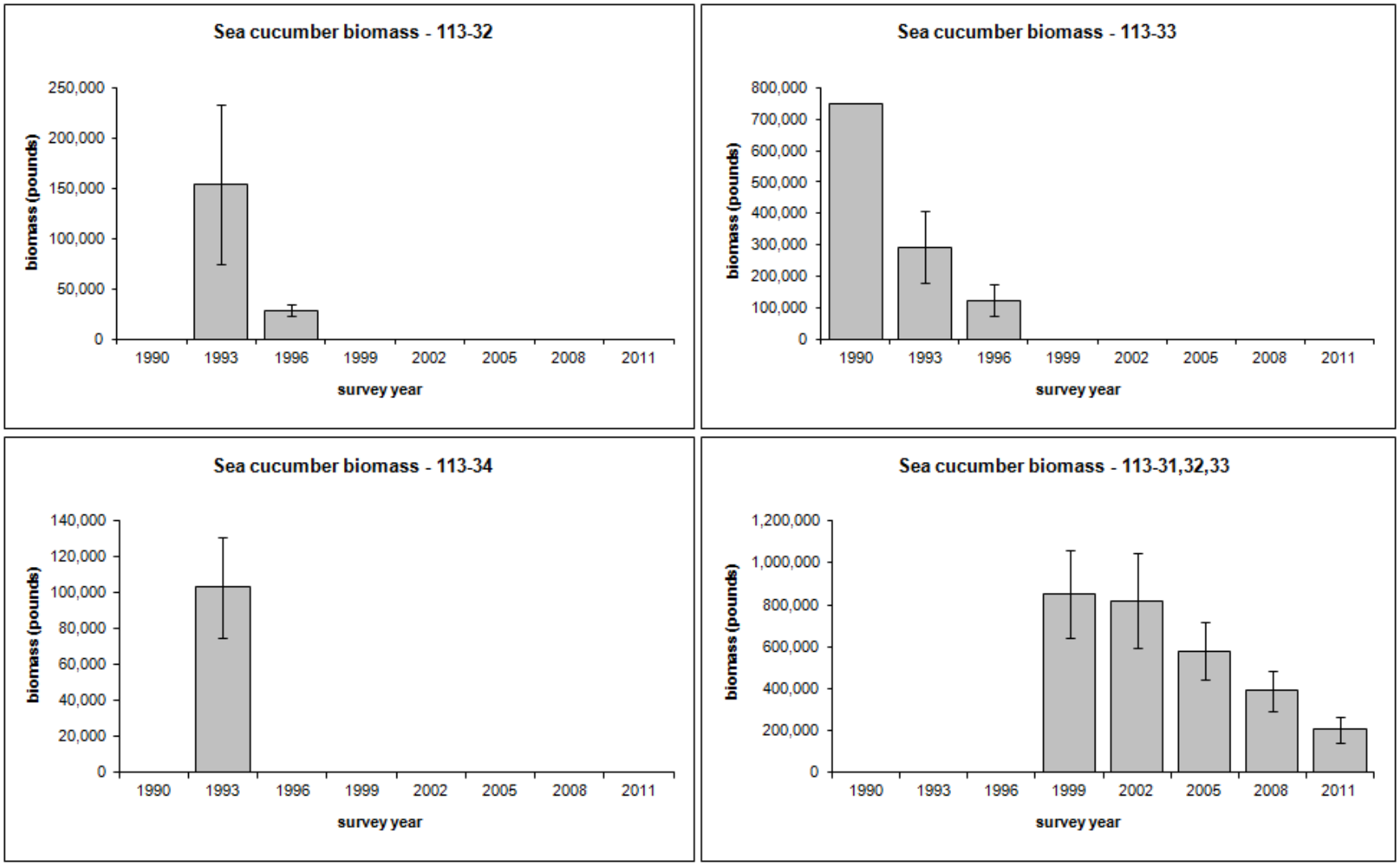


Figure 35.–Total sea cucumber biomass (pounds) from surveys in commercial fishery Subdistrict 113-32, Subdistrict 113-33, Subdistrict 113-34, and Subdistricts 113-31,32,33, in Southeast Alaska. Error bars represent 90% confidence intervals.

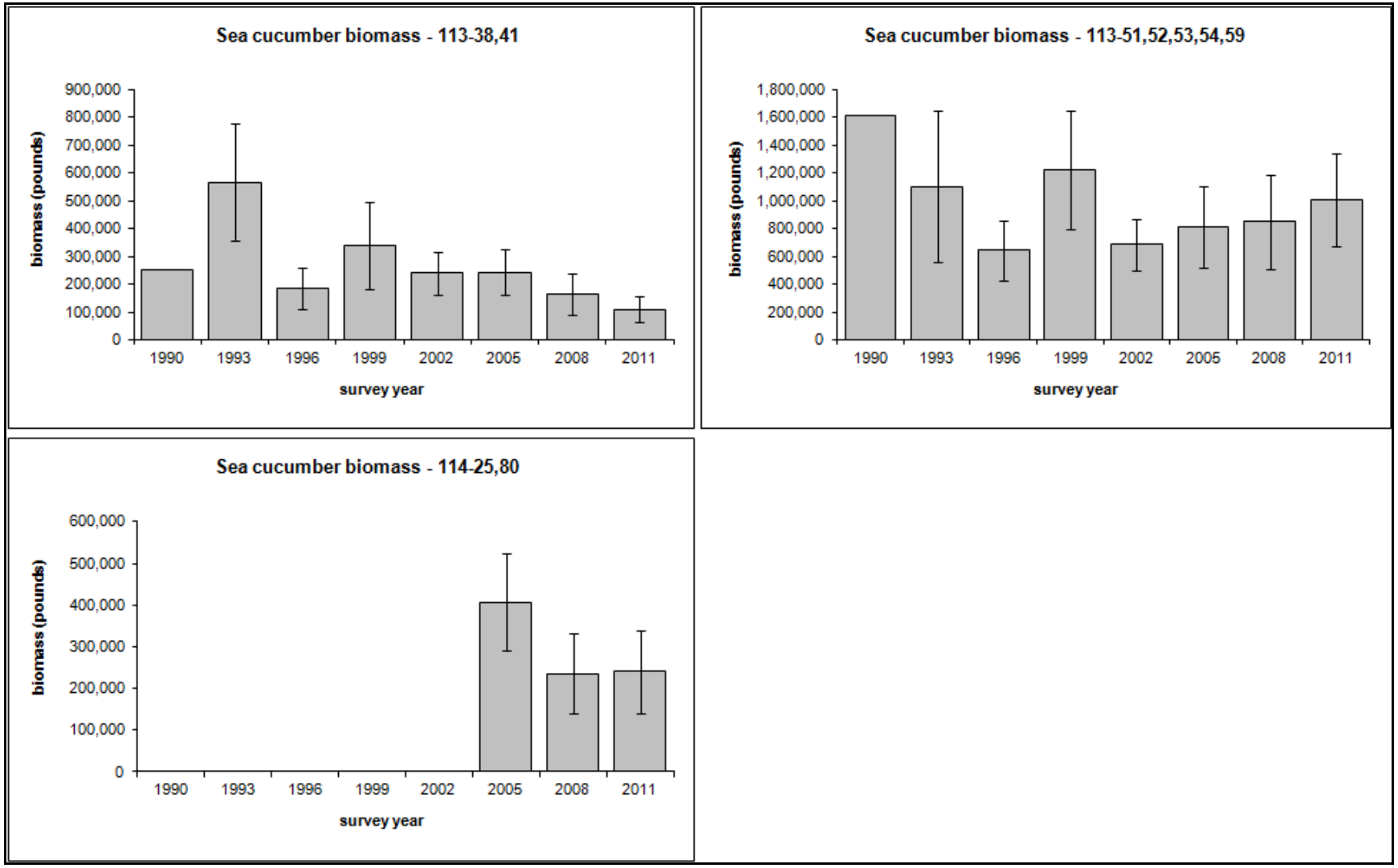


Figure 36.–Total sea cucumber biomass (pounds) from surveys in commercial fishery Subdistricts 113-38,41, Subdistrict 113-51,52,53,54,59, and Subdistricts 114-25,80, in Southeast Alaska. Error bars represent 90% confidence intervals.

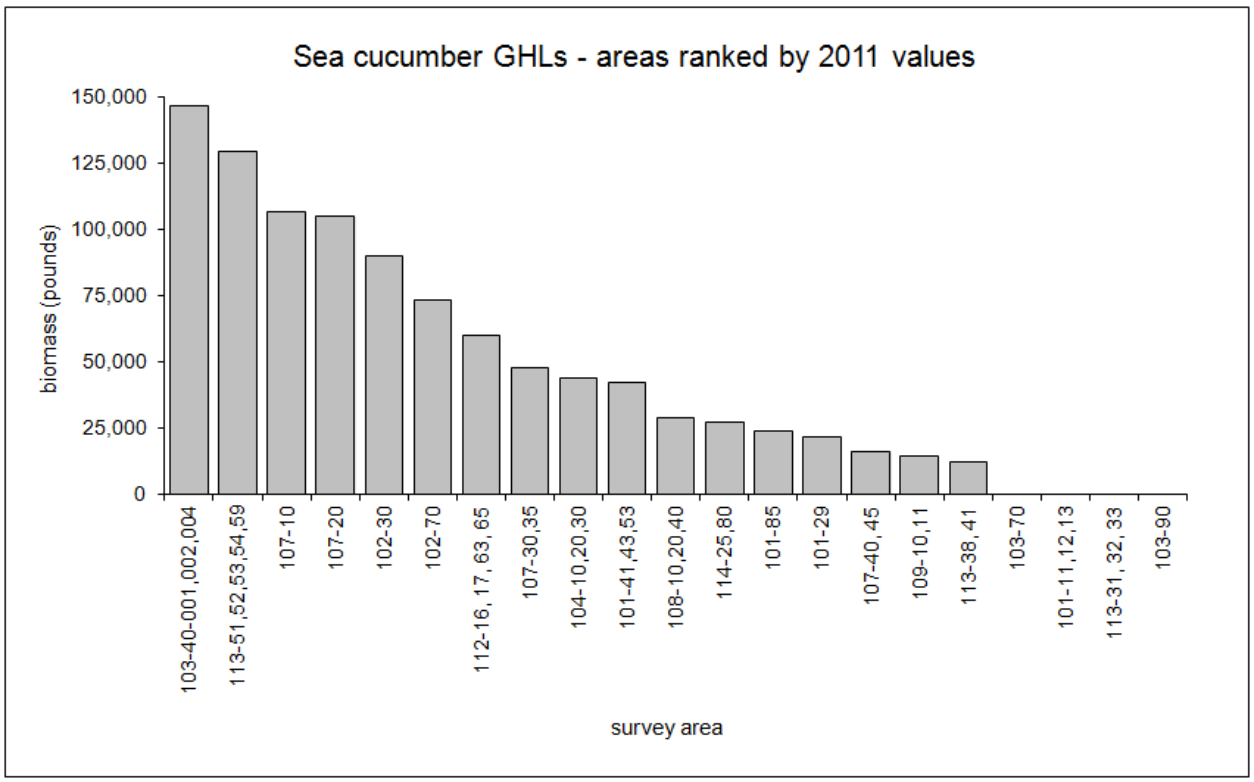


Figure 37.–Sea cucumber commercial fishery guideline harvest levels established for the 2011/2012 fishing season.

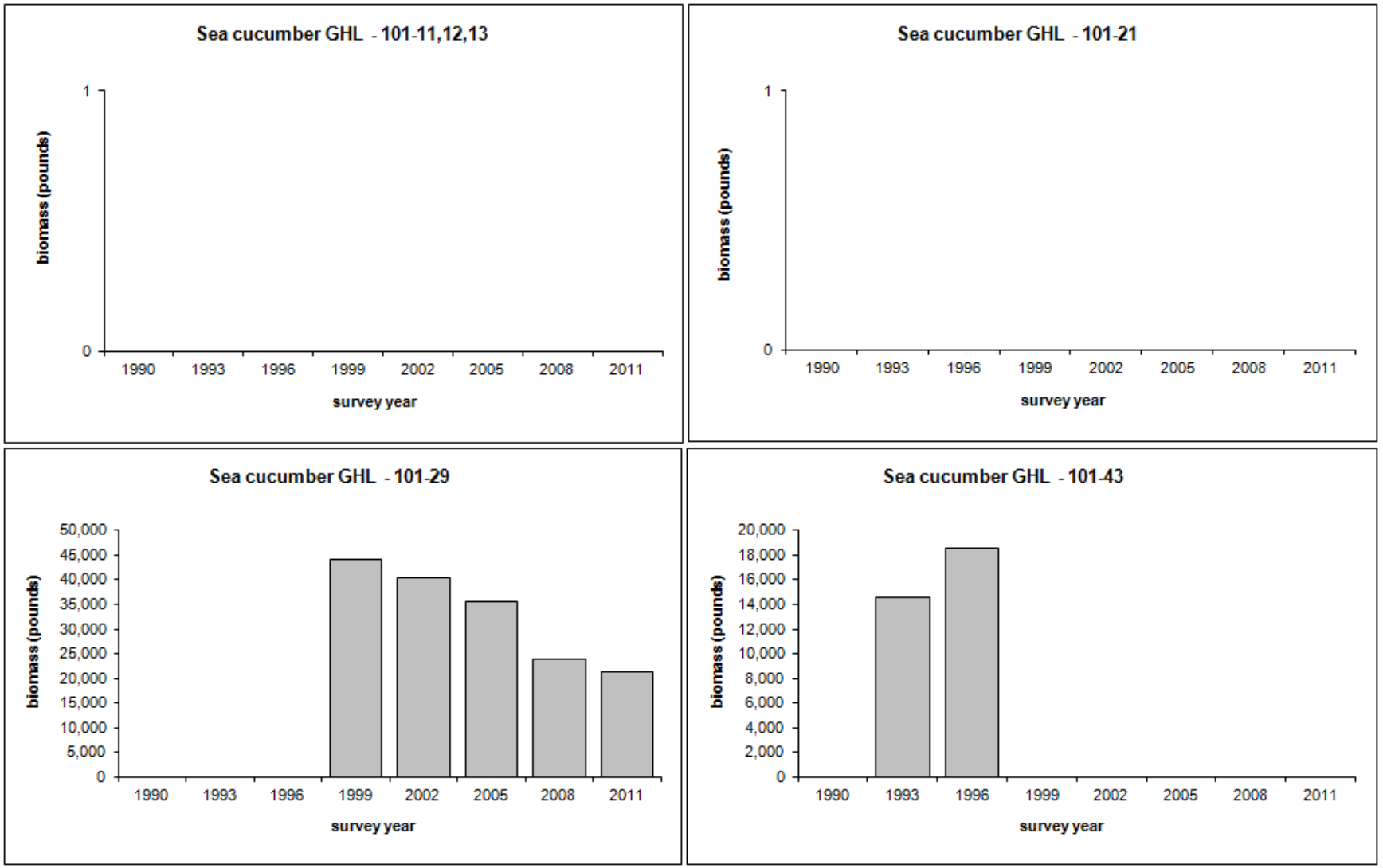


Figure 38.–Actual commercial fishery guideline harvest levels (GHLs) in pounds for fishery Subdistricts 101-11,12,13, Subdistrict 101-21, Subdistrict 101-29, and Subdistrict 101-43, in Southeast Alaska.

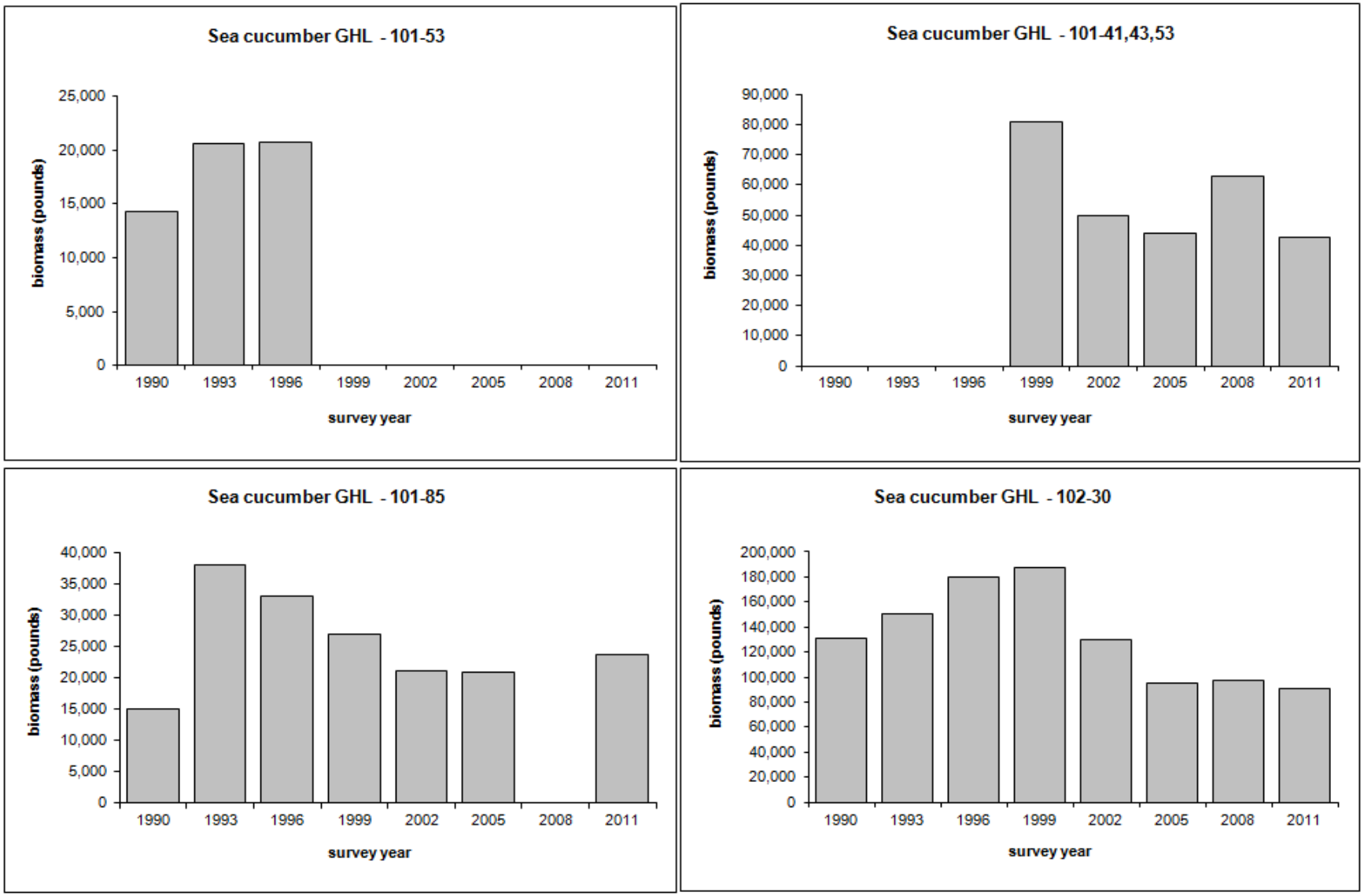


Figure 39.–Actual commercial fishery guideline harvest levels (GHLs) in pounds for fishery Subdistrict 101-53, Subdistricts 101-41,55, 53, Subdistrict 101-85, and Subdistrict 102-30, in Southeast Alaska.

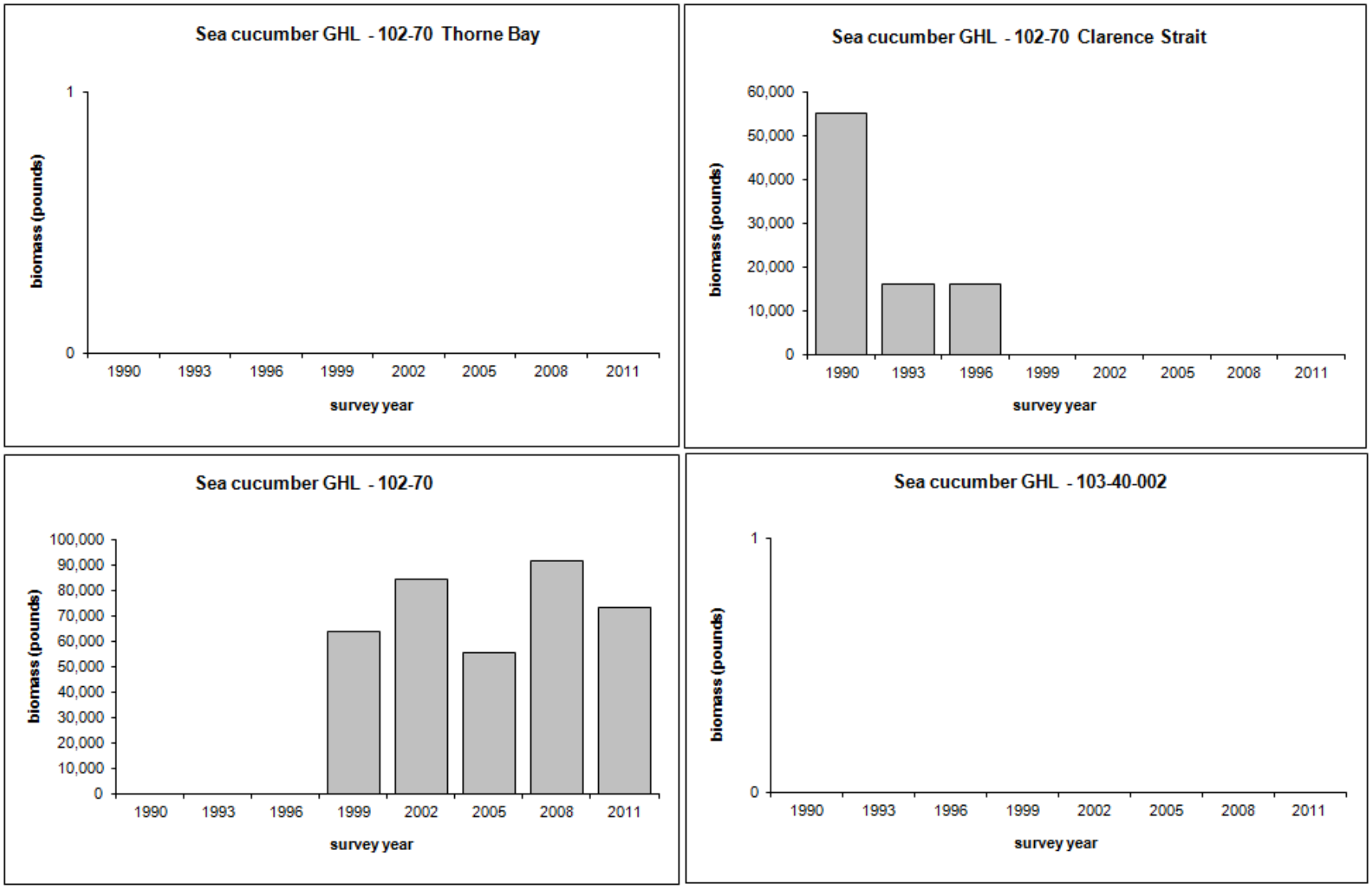


Figure 40.–Actual commercial fishery guideline harvest levels (GHLs) in pounds for fishery Subdistrict 102-70 (Thorne Bay), Subdistrict 102-70 (Clarence Strait), Subdistrict 102-70, and Subdistricts 103-40-002, in Southeast Alaska.

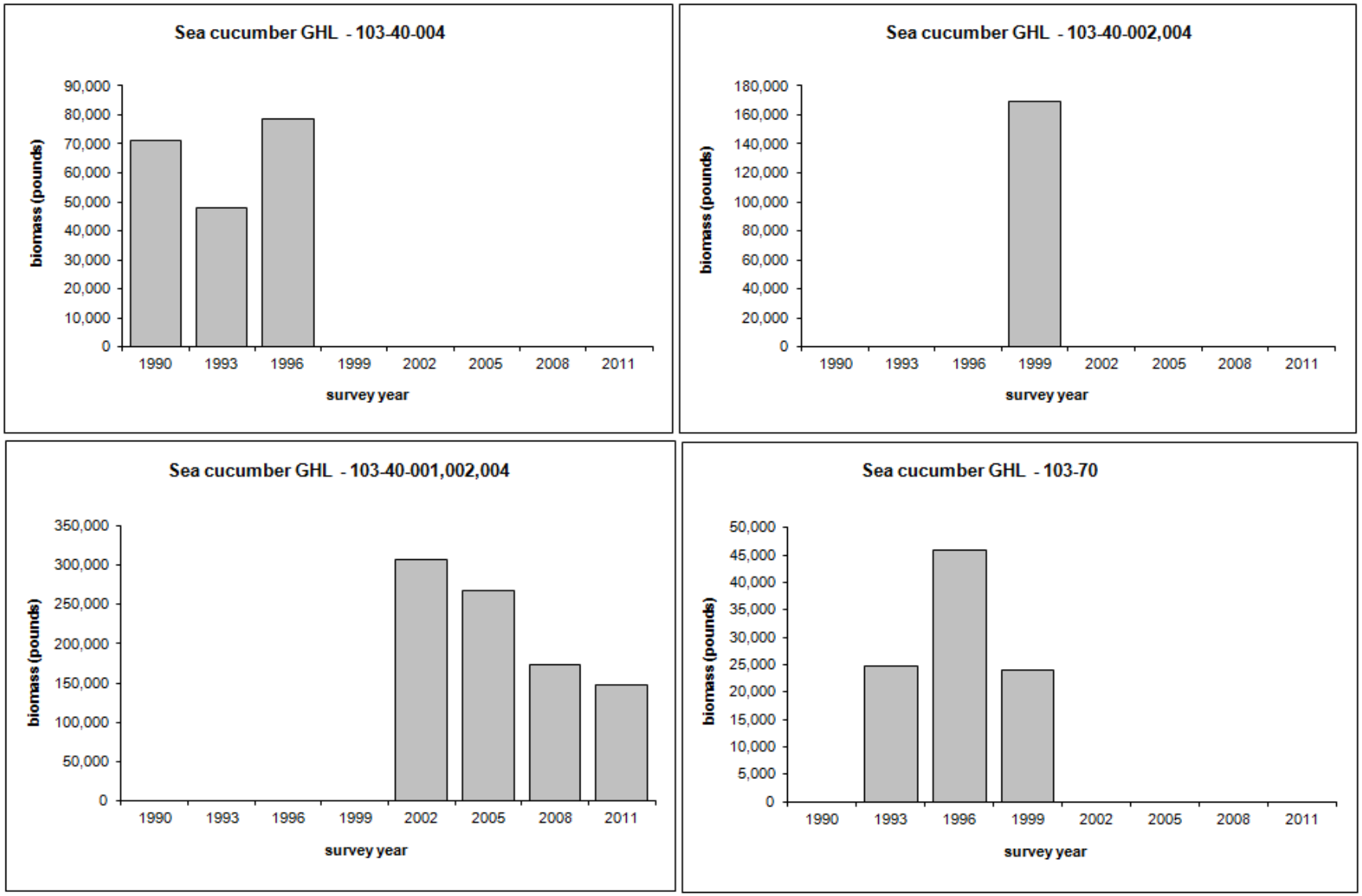


Figure 41.–Actual commercial fishery guideline harvest levels (GHLs) in pounds for fishery Subdistrict 103-40-004, Subdistrict 103-40-001,002,004, Subdistrict 103-40-001,002,004, and Subdistrict 103-70, in Southeast Alaska.

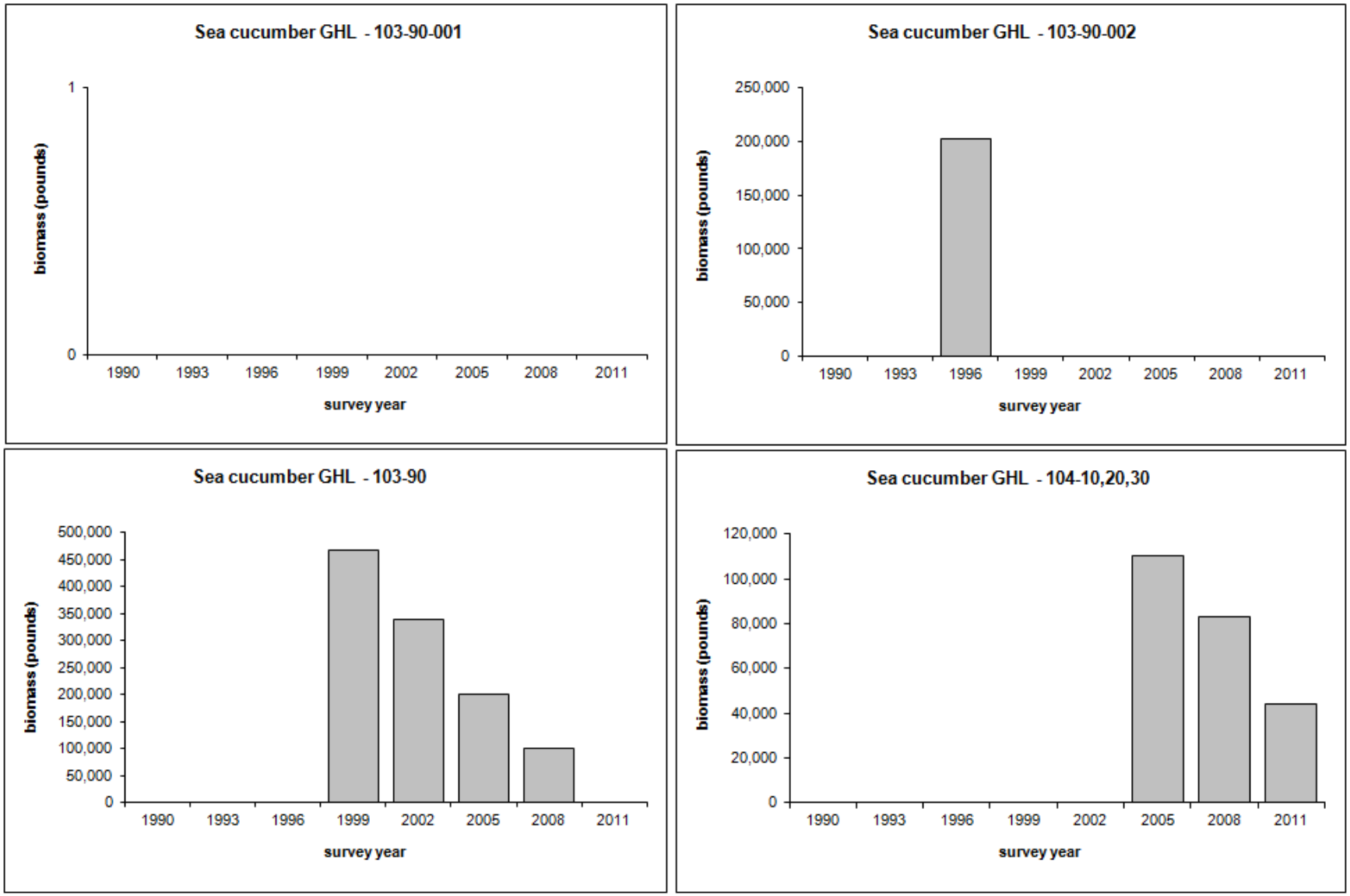


Figure 42.–Actual commercial fishery guideline harvest levels (GHLs) in pounds for fishery Subdistrict 103-90-001, Subdistrict 103-90-002, Subdistrict 103-90, and Subdistricts 104-10,20,30, in Southeast Alaska.

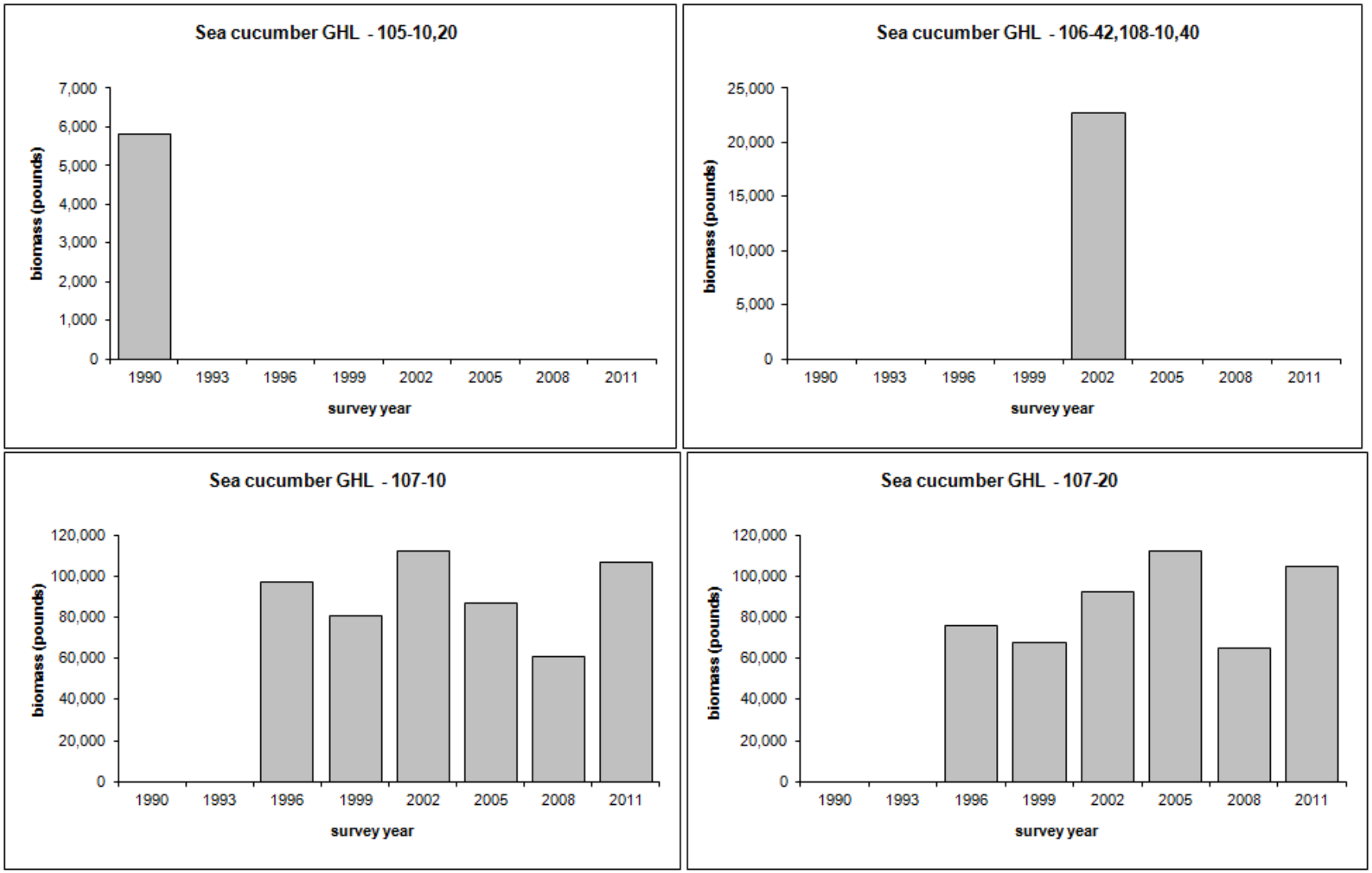


Figure 43.–Actual commercial fishery guideline harvest levels (GHLs) in pounds for fishery Subdistricts 105-10,20, Subdistricts 106-42,108-10,40, Subdistrict 107-10, and Subdistrict 107-20, in Southeast Alaska.

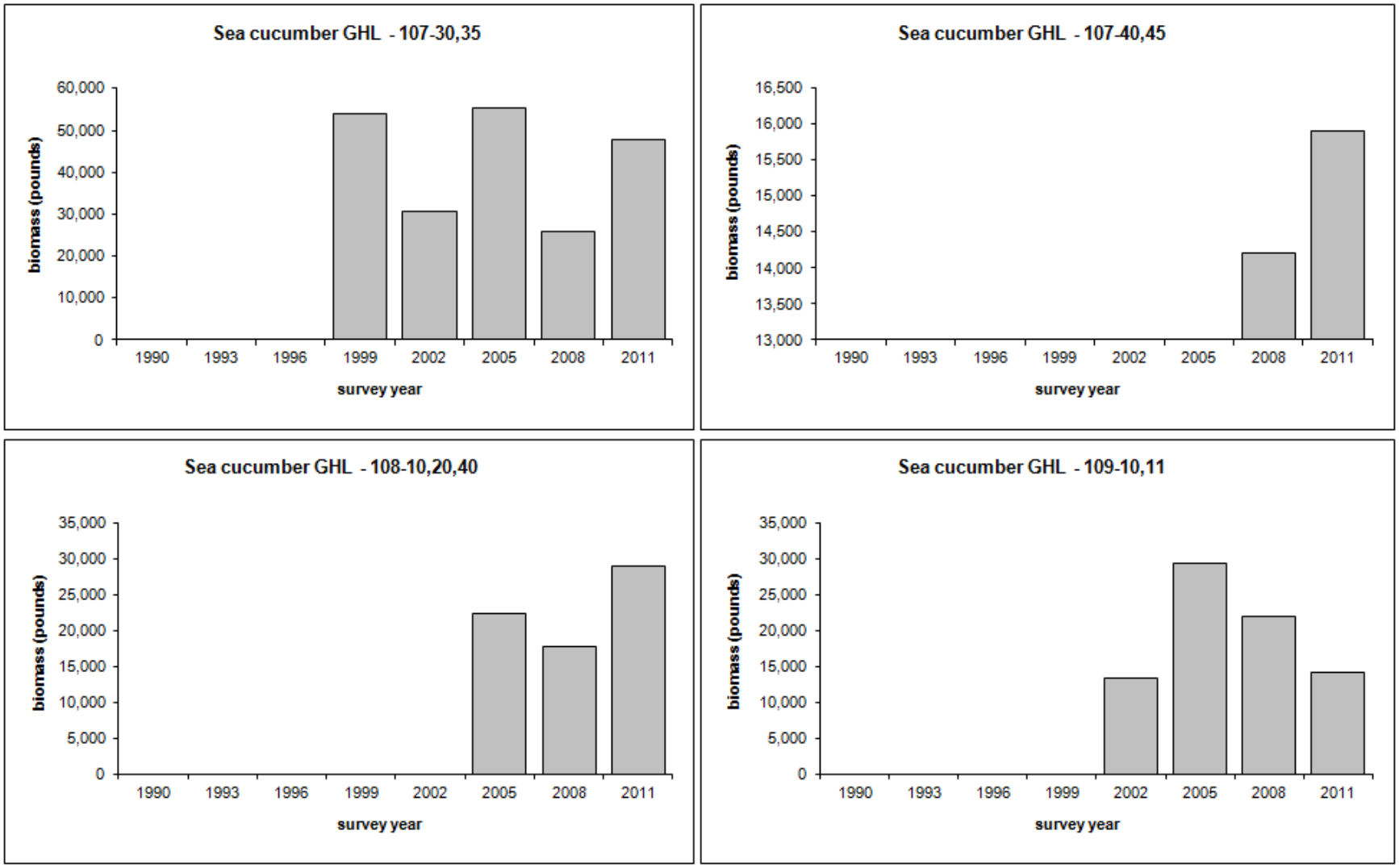


Figure 44.–Actual commercial fishery guideline harvest levels (GHLs) in pounds for fishery Subdistricts 107-30,35, Subdistricts 107-40,45, Subdistrict 108-10,20,40, and Subdistricts 109-10,11, in Southeast Alaska.

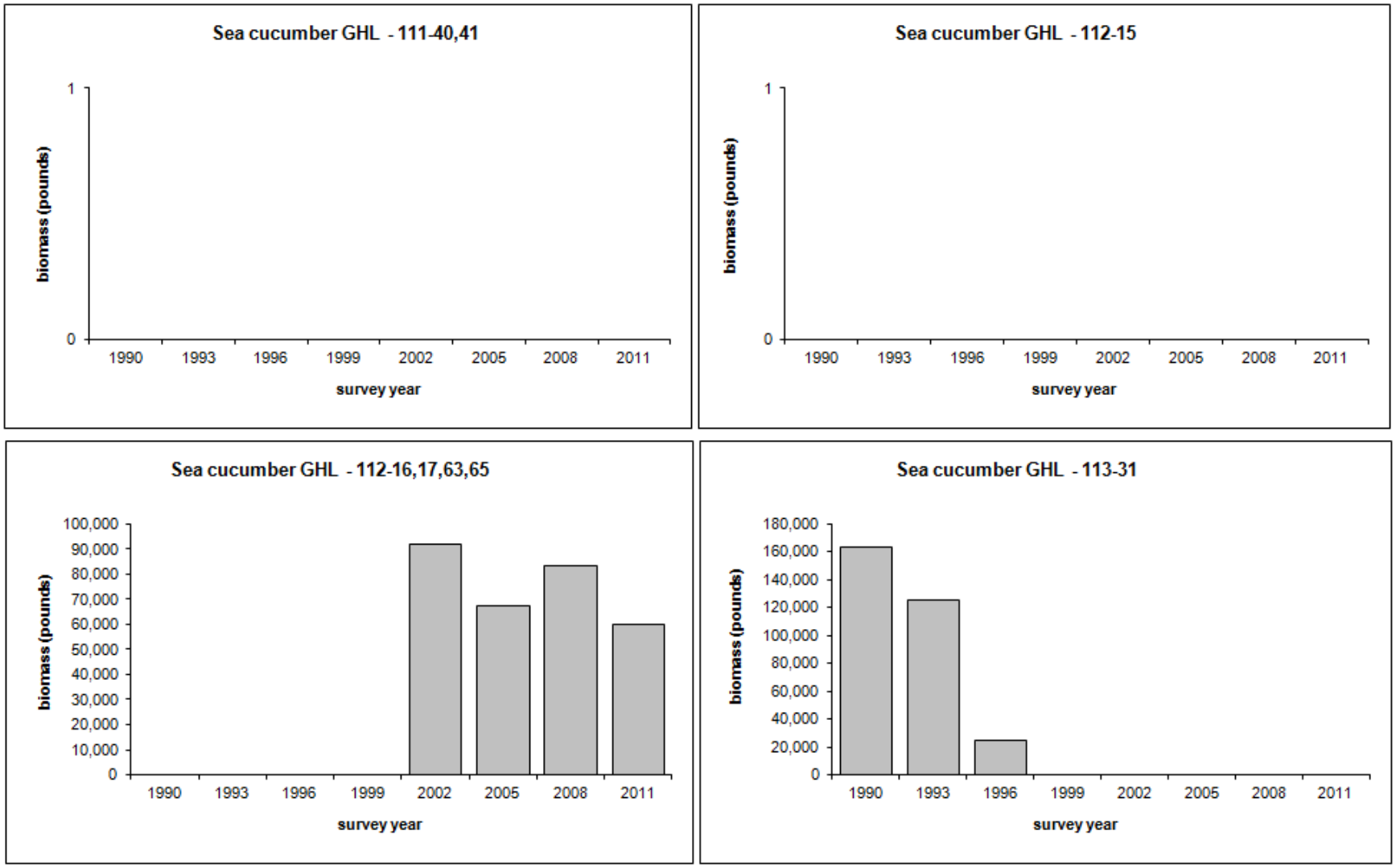


Figure 45.–Actual commercial fishery guideline harvest levels (GHLs) in pounds for fishery Subdistricts 111-40,41, Subdistrict 112-15, Subdistricts 112-16,17,63,65, and Subdistrict 113-31, in Southeast Alaska.

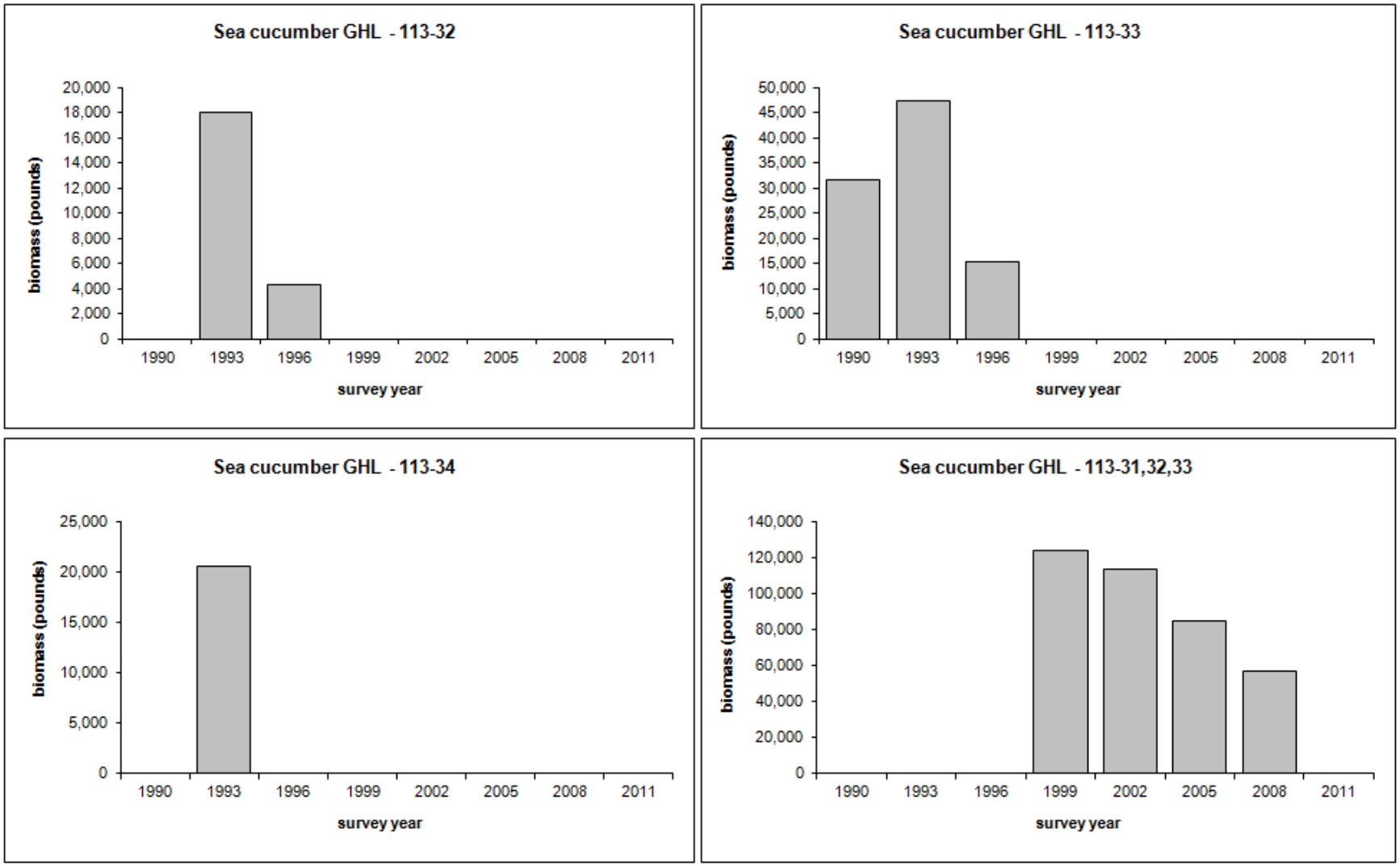


Figure 46.–Actual commercial fishery guideline harvest levels (GHLs) in pounds for fishery Subdistrict 113-32, Subdistrict 113-33, Subdistrict 113-34, and Subdistricts 113-31,32,33, in Southeast Alaska.

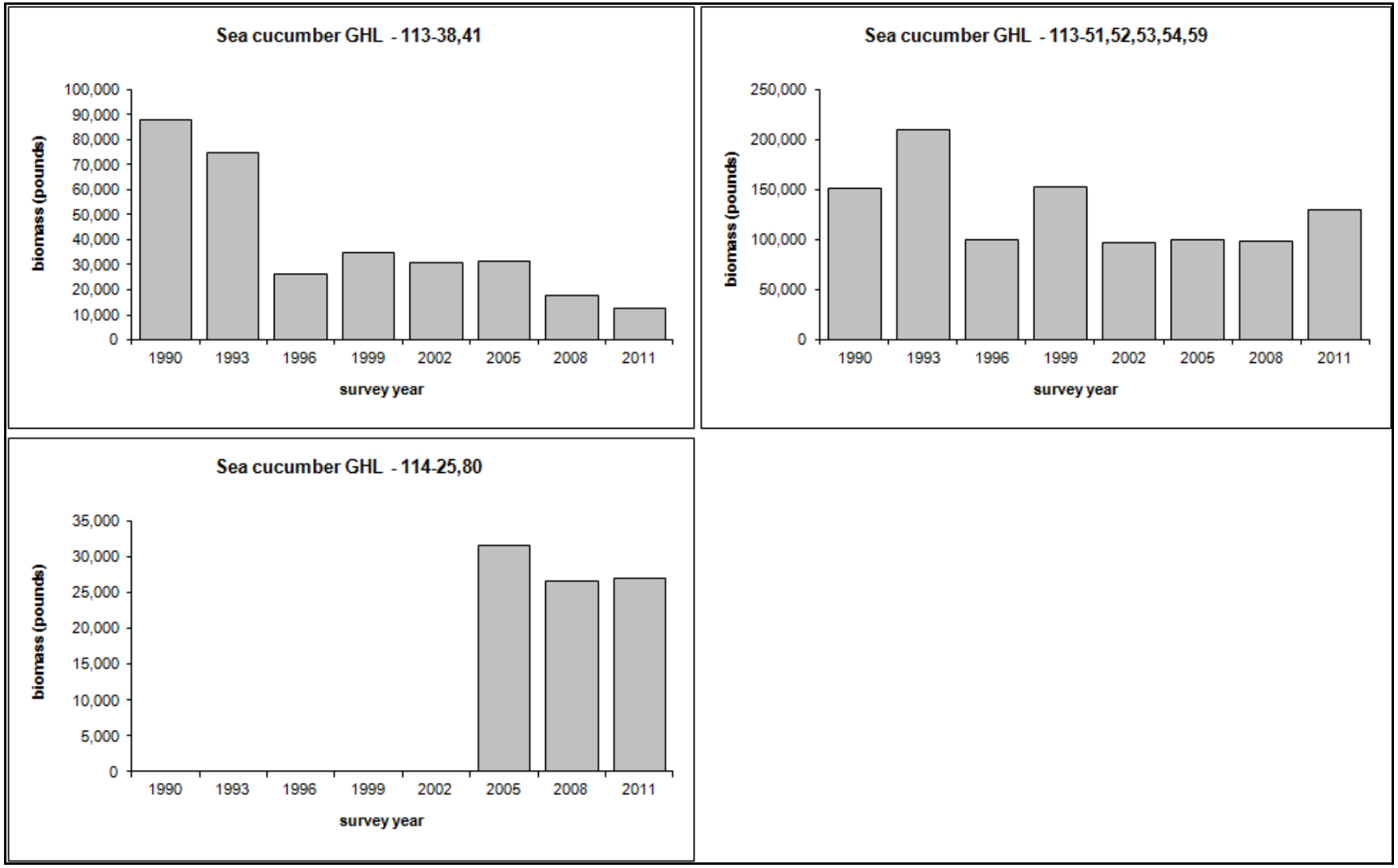


Figure 47.–Actual commercial fishery guideline harvest levels (GHLs) in pounds for fishery Subdistricts 113-38,41, Subdistricts 113-51,52,53,54,59, and Subdistricts 114-25,80, in Southeast Alaska.

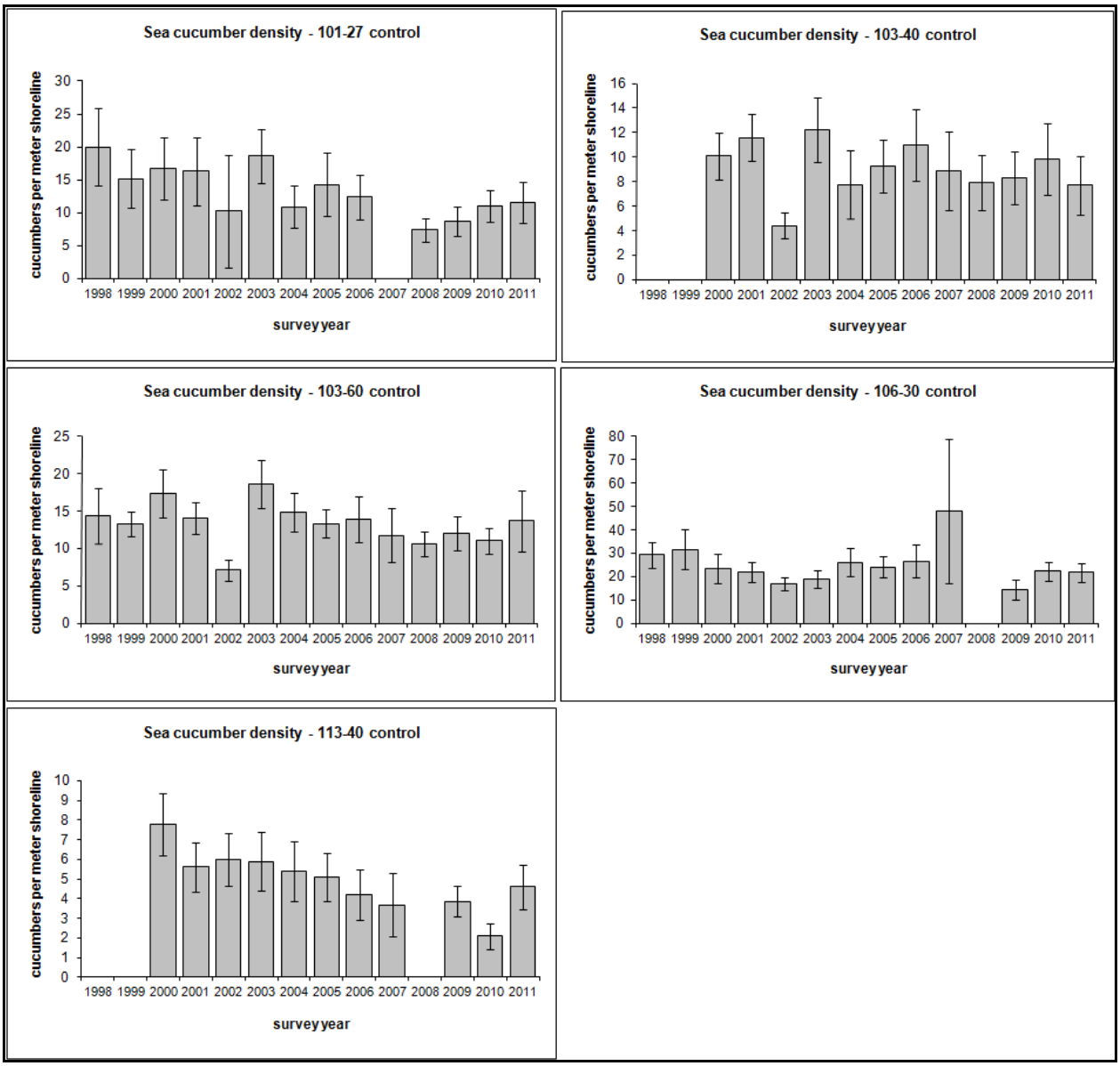


Figure 48.–Average number of sea cucumbers per meter of shoreline from surveys in control area (closed to commercial harvest) Subdistrict 101-27, Subdistrict 103-40, Subdistrict 103-60, Subdistrict 106-30, and Subdistrict 113-41 in Southeast Alaska. Error bars represent 90% confidence intervals.

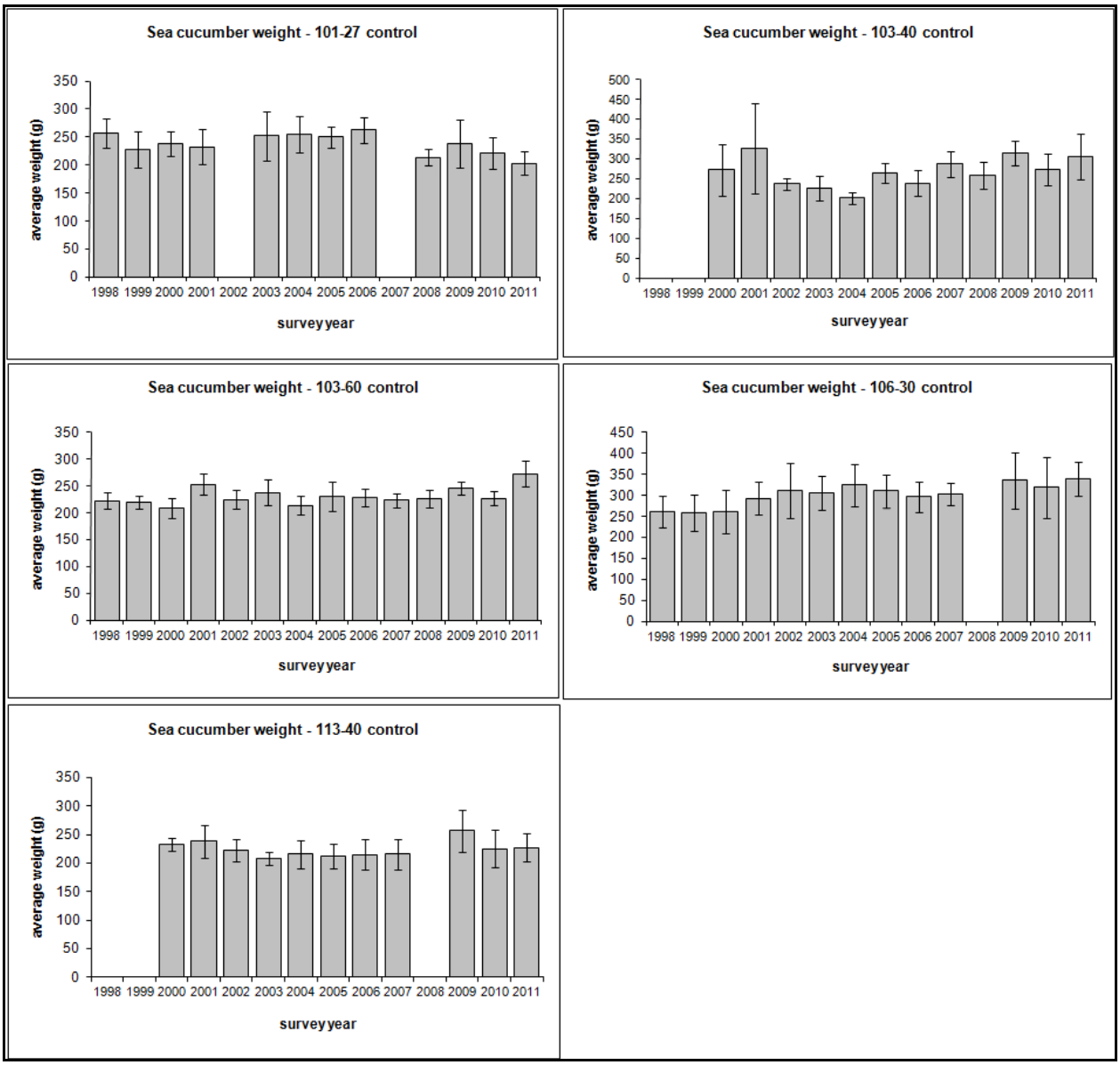


Figure 49.–Average sea cucumbers weight (grams) from surveys in control area (closed to commercial harvest) Subdistrict 101-27, Subdistrict 103-40, Subdistrict 103-60, Subdistrict 106-30, and Subdistrict 113-41 in Southeast Alaska. Error bars represent 90% confidence intervals.

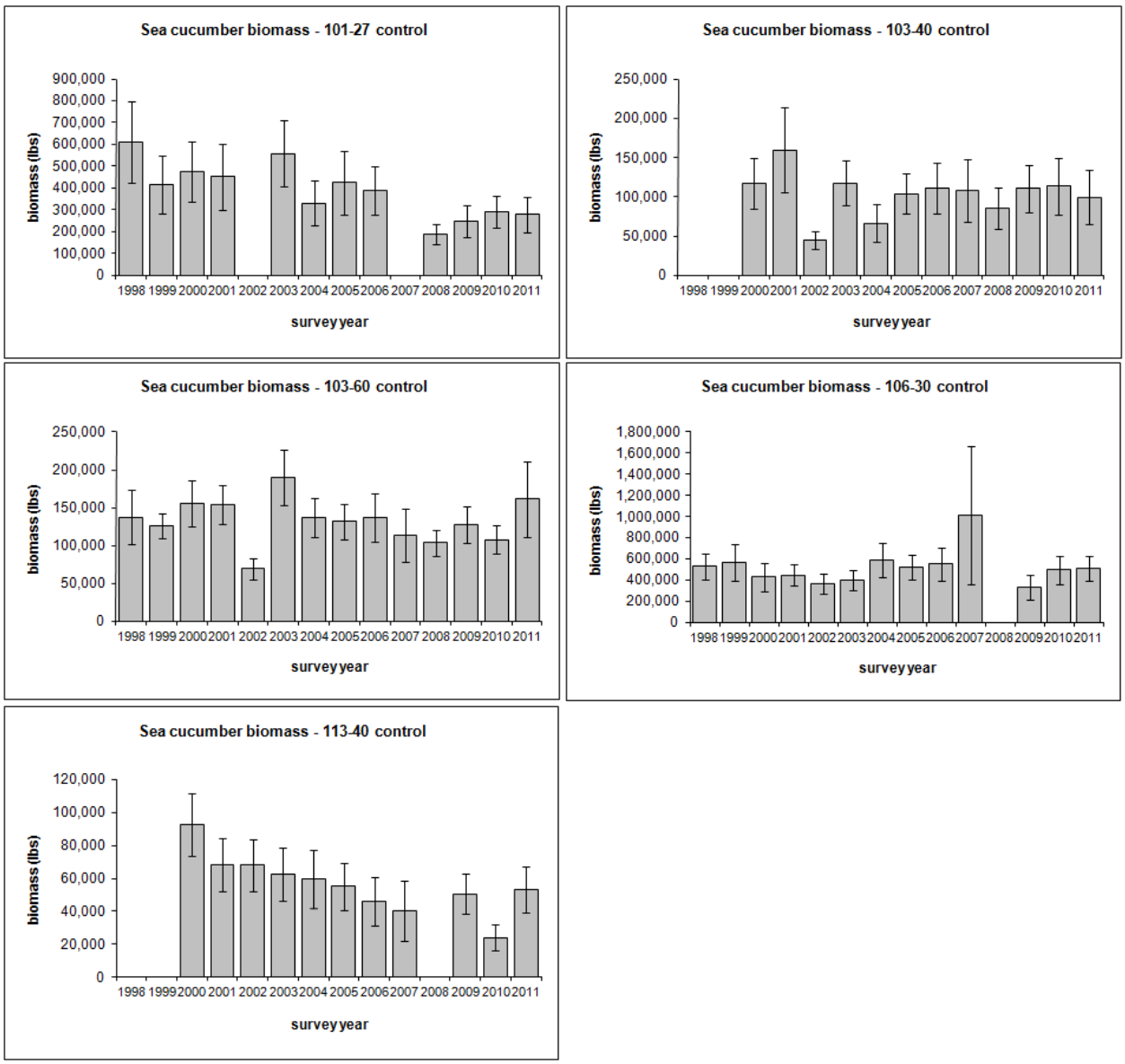


Figure 50.–Total sea cucumber biomass (pounds) from surveys in control area (closed to commercial harvest) Subdistrict 101-27, Subdistrict 103-40, Subdistrict 103-60, Subdistrict 106-30, and Subdistrict 113-41 in Southeast Alaska. Error bars represent 90% confidence intervals.

APPENDIX A: KEY TO SUBSTRATE TYPES

Appendix A.1.–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*

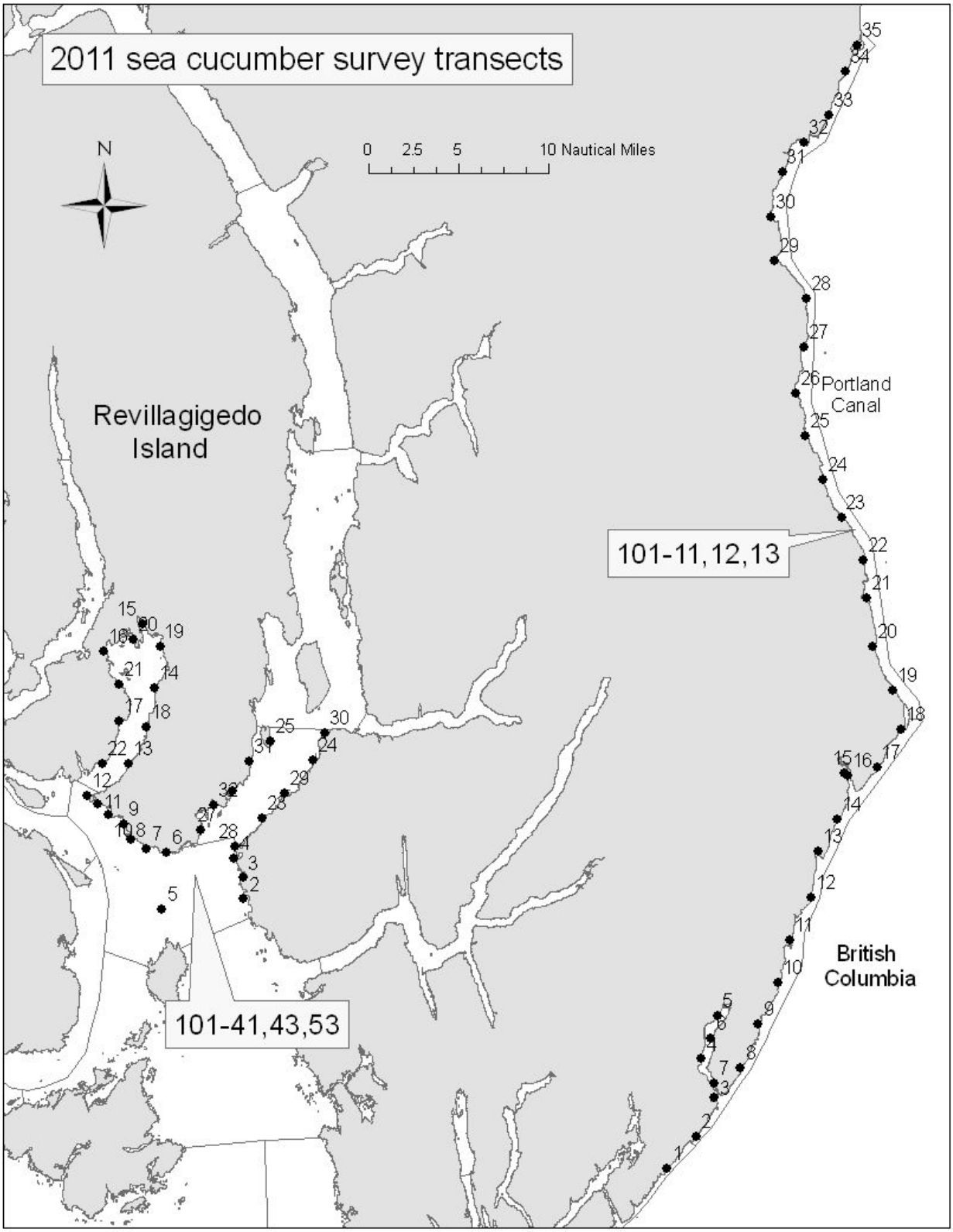
APPENDIX B: KEY TO BOTTOM TYPES

Appendix B.1– Key to bottom types used for herring spawn deposition survey.

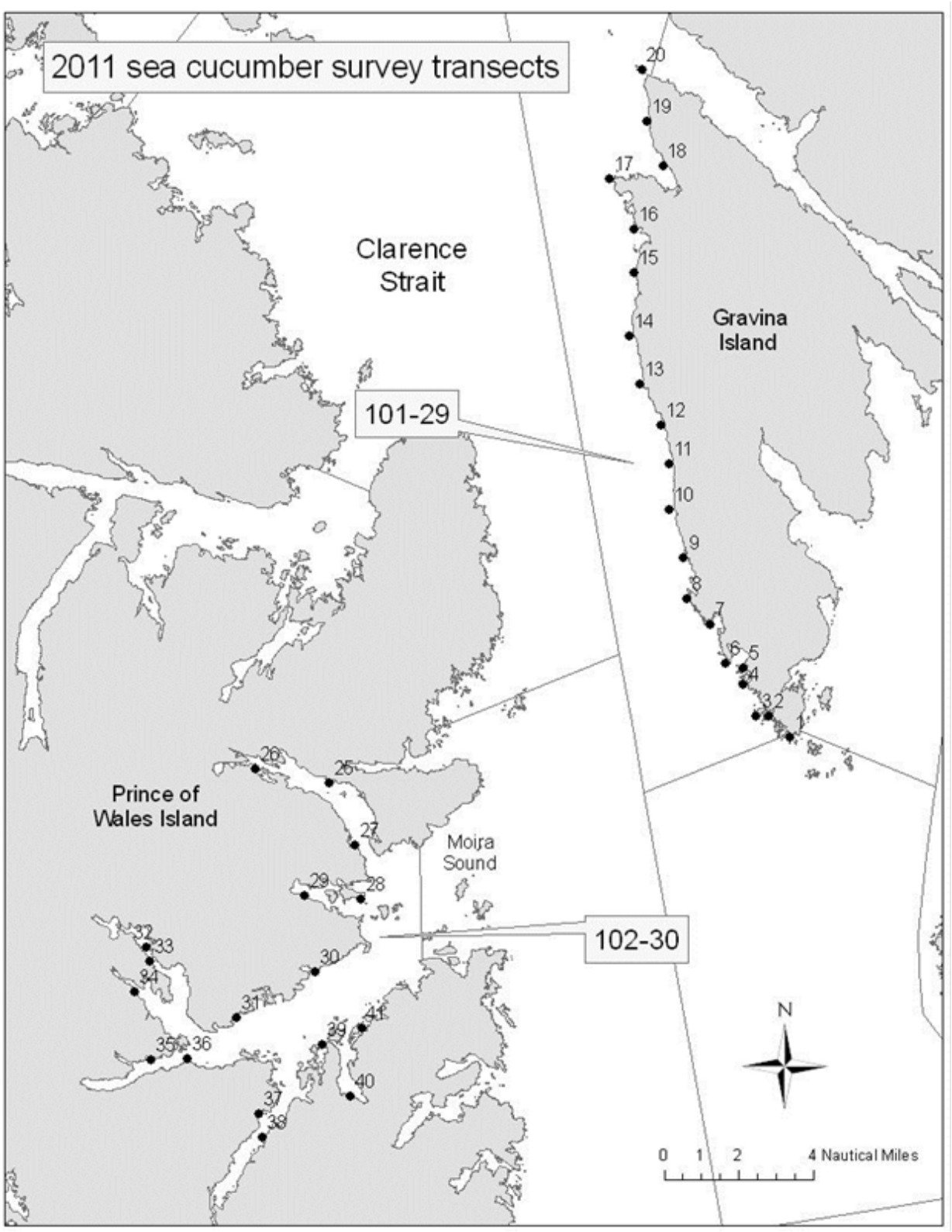
Code	Expanded code	Definition
RCK	Bedrock	Various rocky substrates > 1 m in diameter
BLD	Boulder	Substrate between 25 cm and 1 m
CBL	Cobble	Substrate between 6 cm and 25 cm
GVL	Gravel	Substrate between 0.4 cm and 6 cm
SND	Sand	Clearly separate grains of < 0.4 cm
MUD	Mud	Soft, paste-like material
SIL	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 2011

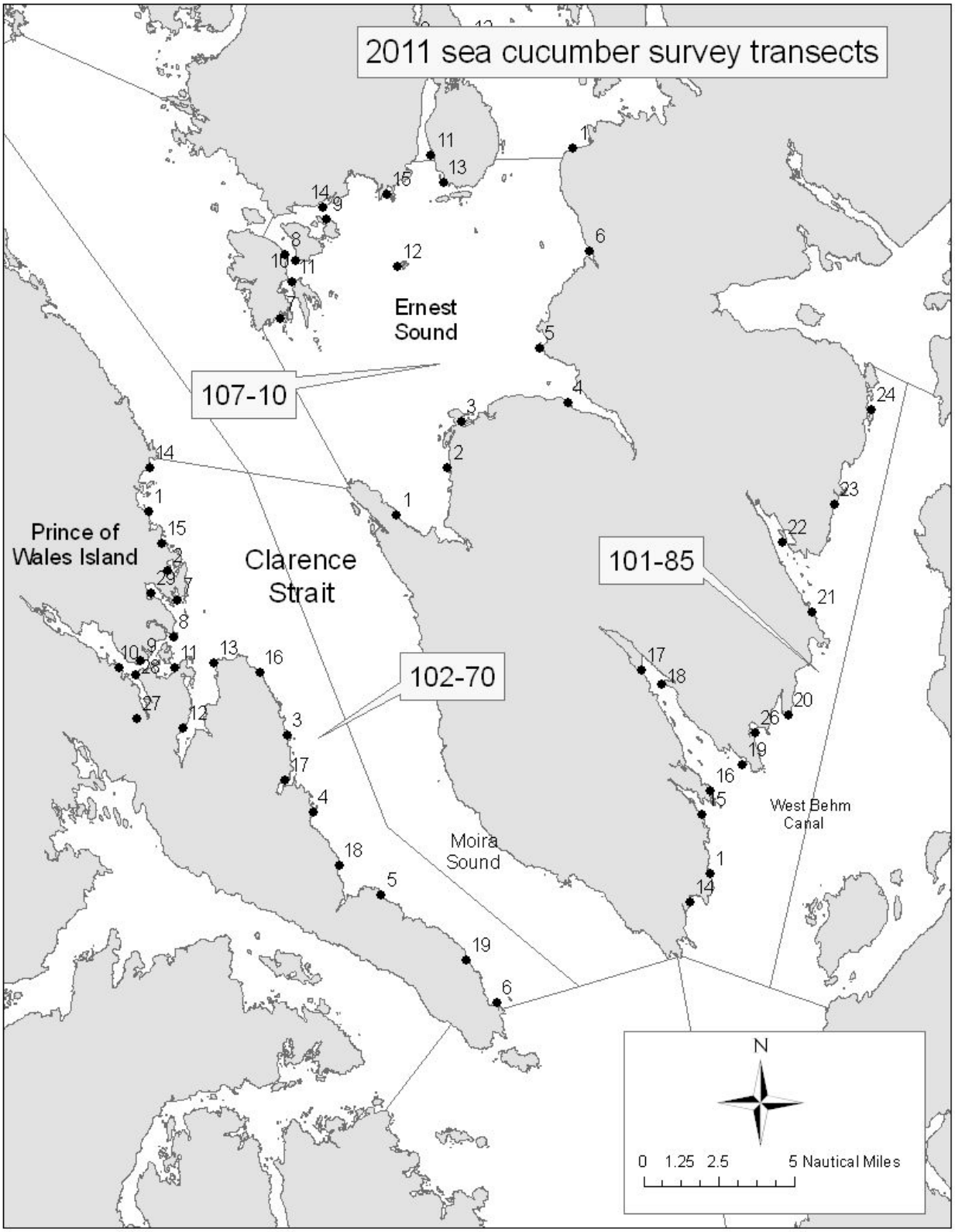
Appendix C1.–Location of transects surveyed in 2011 for commercial fishery Subdistricts 101-11,12,13 and Subdistricts 101-41,43,53. Black lines indicate fishery area boundaries.



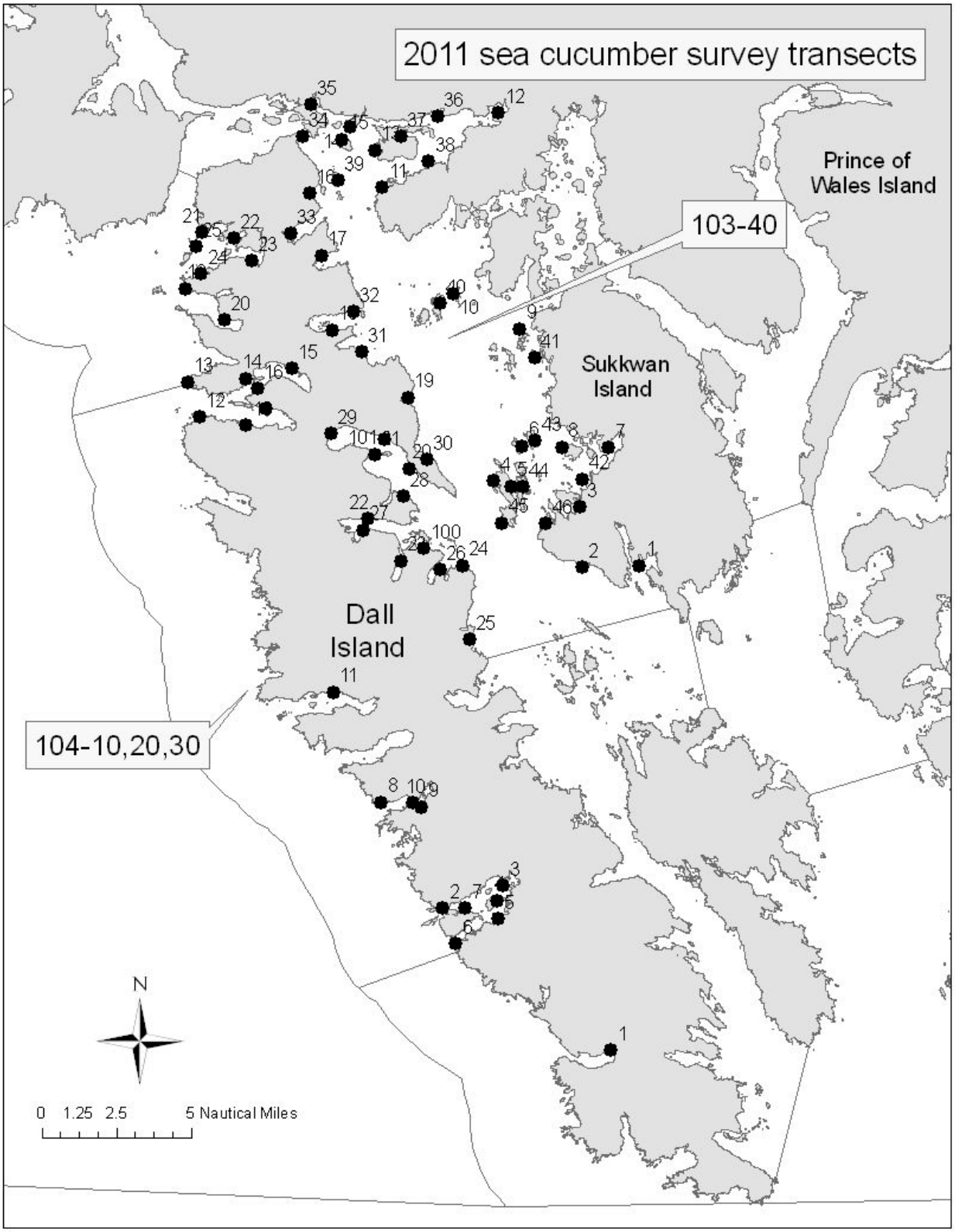
Appendix C2.–Location of transects surveyed in 2011 for commercial fishery Subdistrict 101-29 and Subdistrict 102-30. Black lines indicate fishery area boundaries.



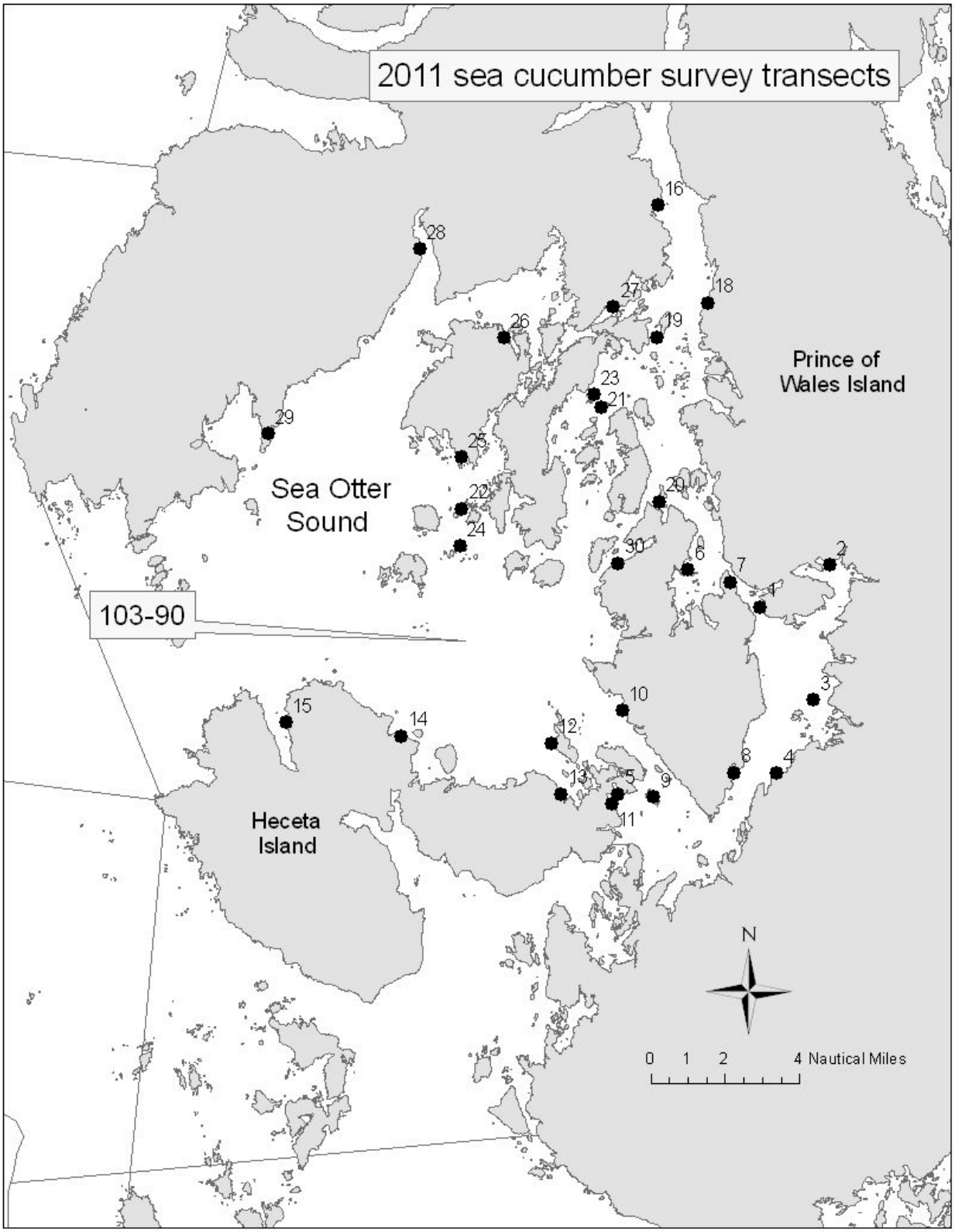
Appendix C3.–Location of transects surveyed in 2011 for commercial fishery Subdistricts 101-85, Subdistrict 102-70, and 107-10. Black lines indicate fishery area boundaries.



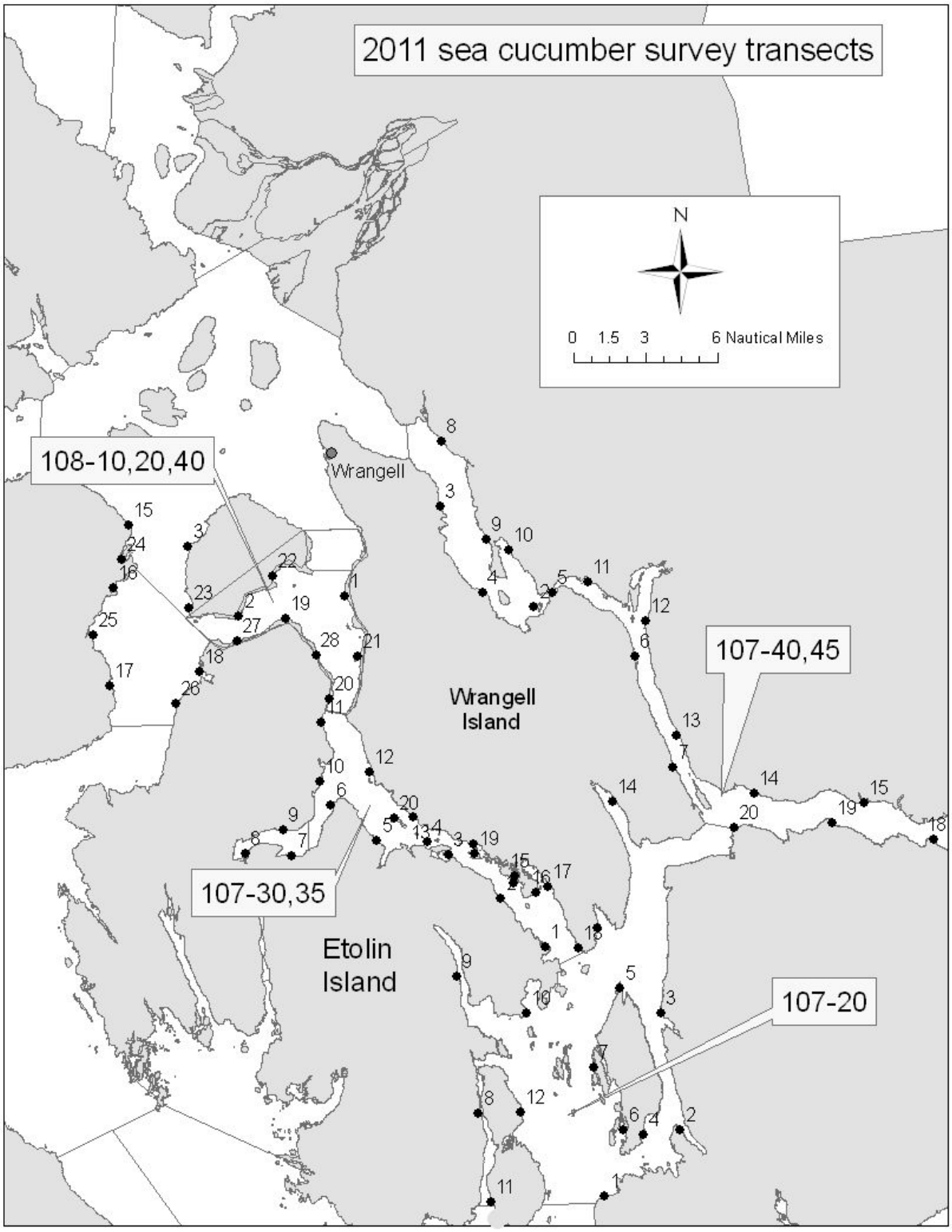
Appendix C4.–Location of transects surveyed in 2011 for commercial fishery Subdistrict 103-40 and Subdistricts 104-10,20,30. Black lines indicate fishery area boundaries.



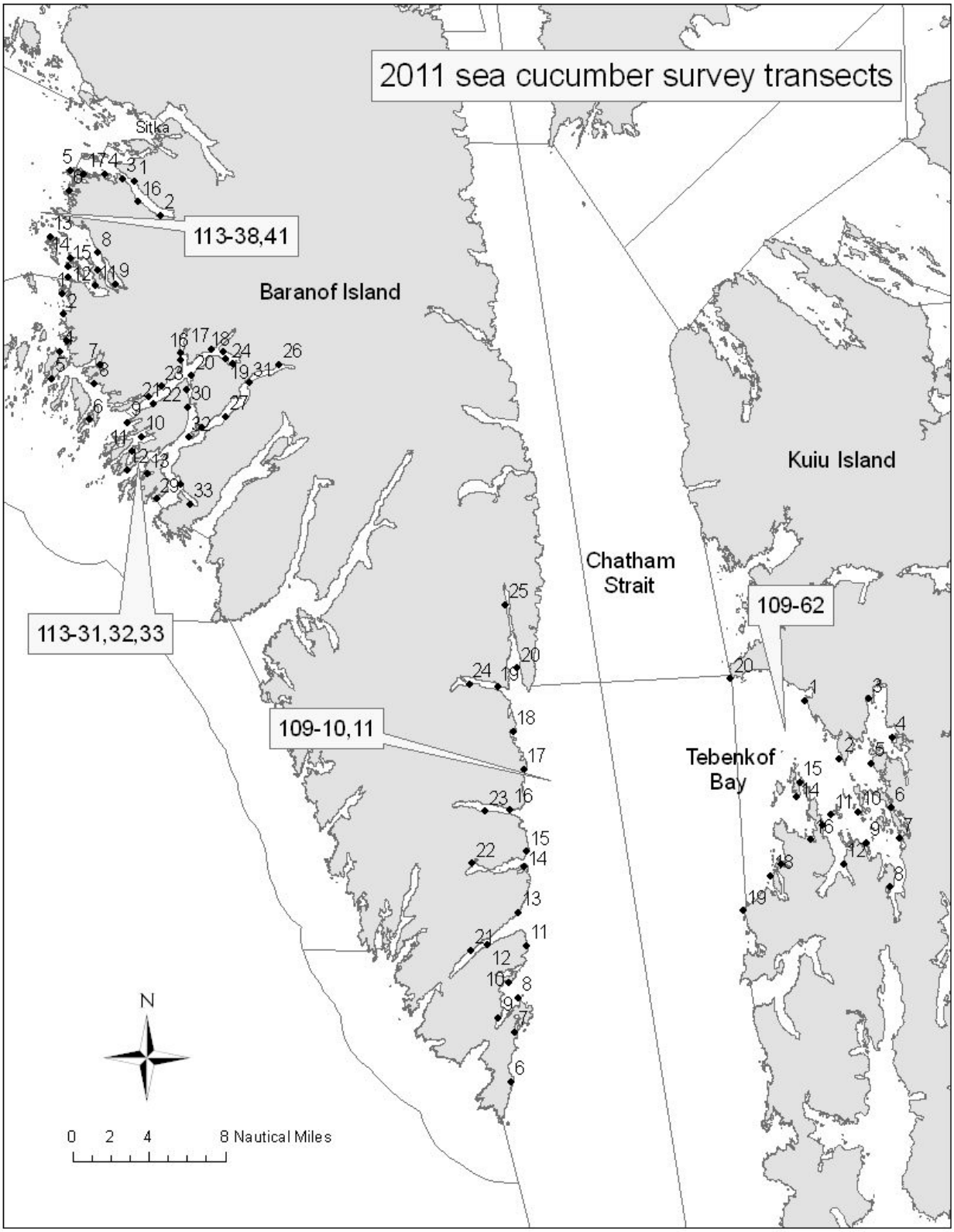
Appendix C5.–Location of transects surveyed in 2011 for commercial fishery Subdistrict 103-90. Black lines indicate fishery area boundaries.



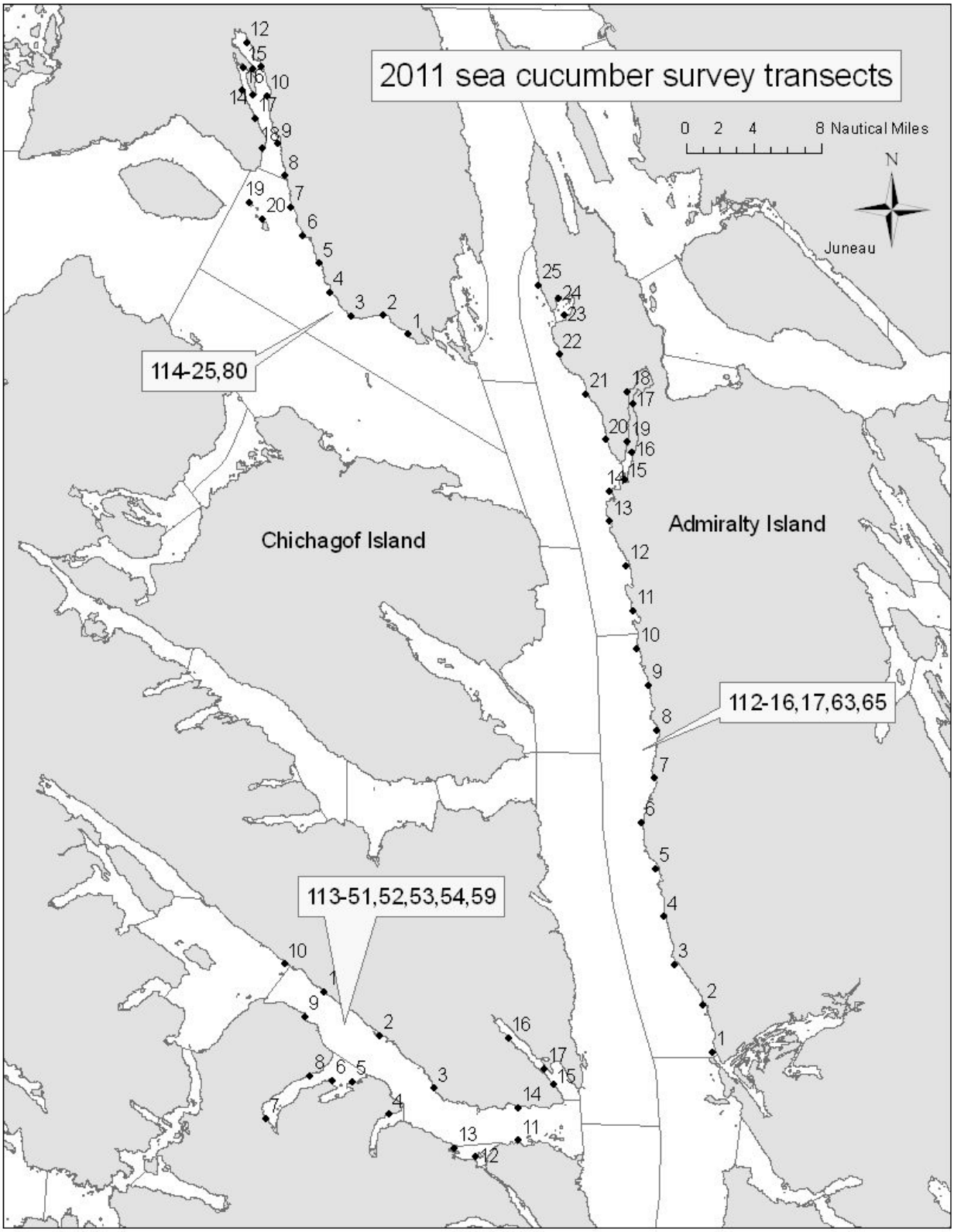
Appendix C6.–Location of transects surveyed in 2011 for Subdistrict 107-20, Subdistricts 107-30,35, Subdistricts 107-40,45, and Subdistricts 108-10,20,40. Black lines indicate fishery area boundaries.



Appendix C7.–Location of transects surveyed in 2011 for commercial fishery Subdistricts 109-10,11, 109-62, 113-31,32,33, and 113-38,41. Black lines indicate fishery area boundaries.

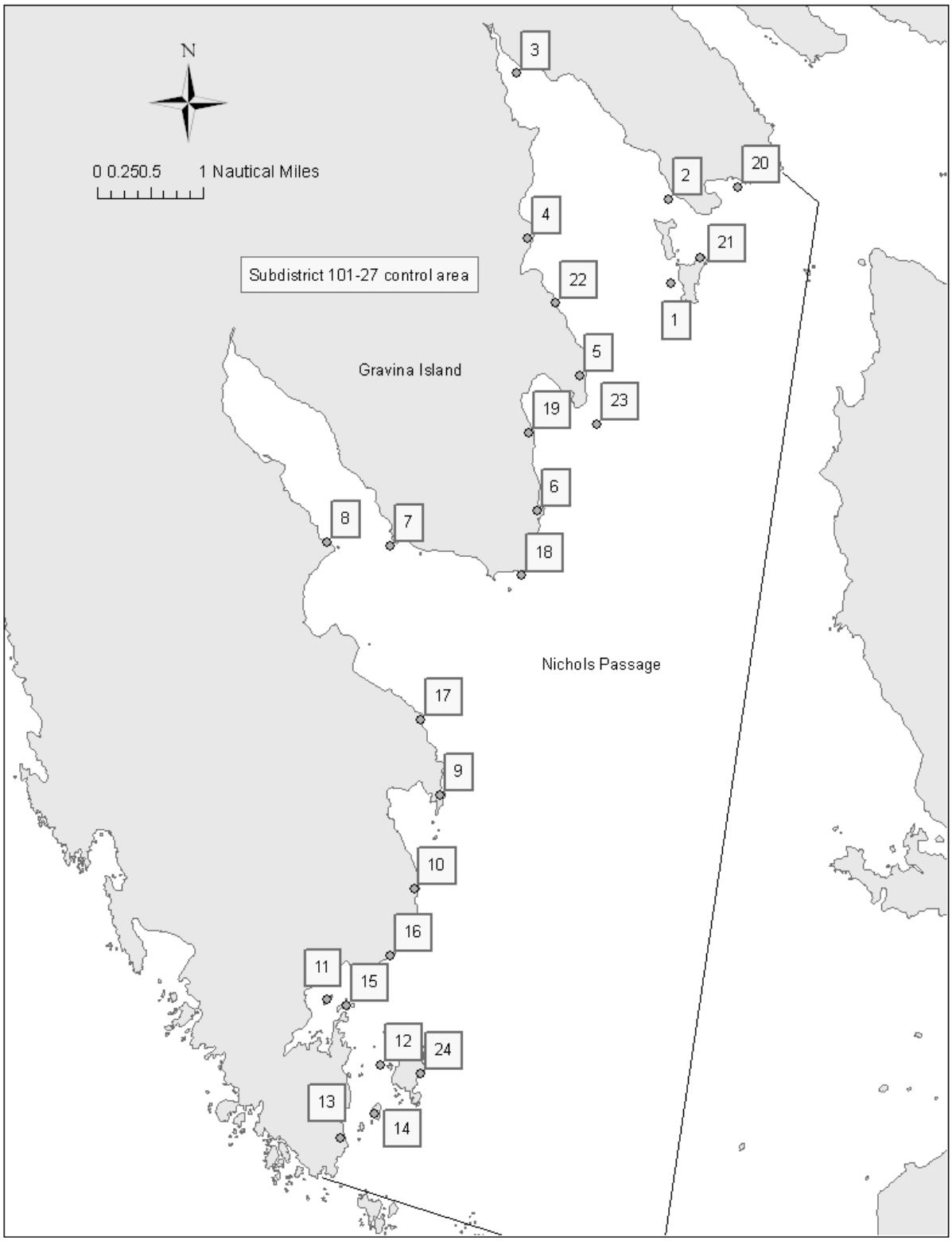


Appendix C8.–Location of transects surveyed in 2011 for commercial fishery Subdistricts 113-51,52,53,54,59, 112-16,17,63,65, and 114-25,80. Black lines indicate fishery area boundaries.

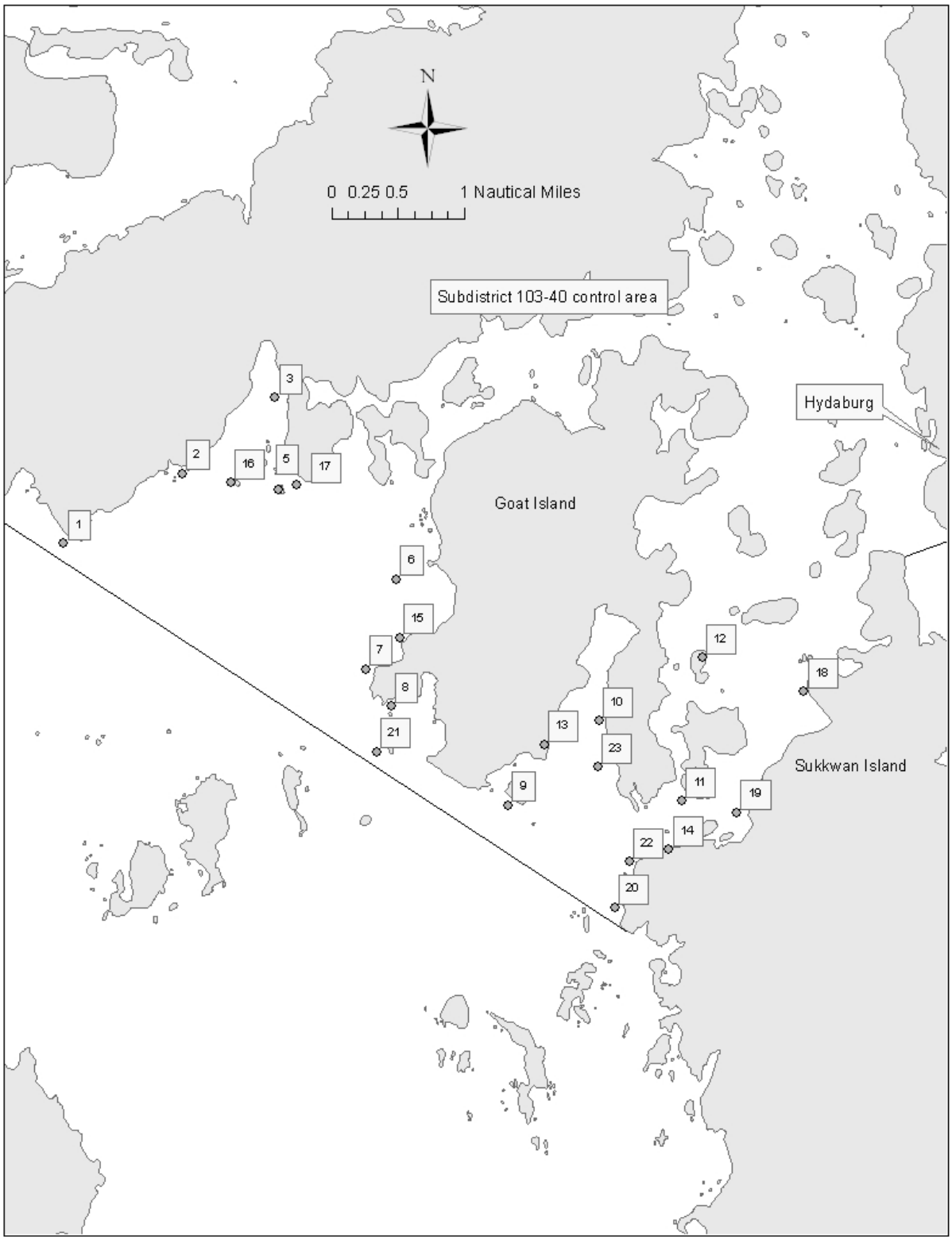


APPENDIX D: MAPS DISPLAYING CONTROL AREAS AND LOCATIONS OF TRANSECTS

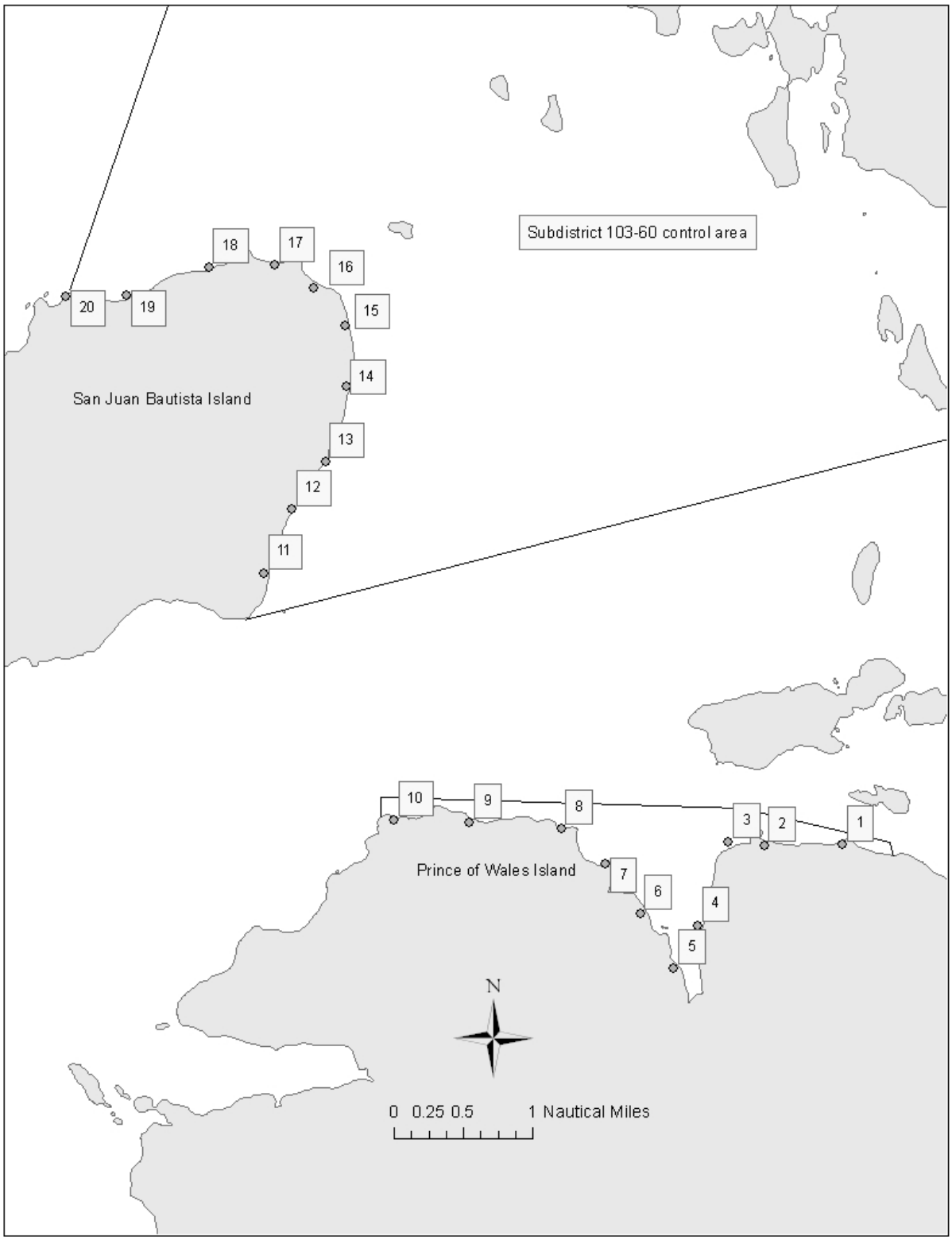
Appendix D1.–Location of transects for control area Subdistrict 101-27. Black line indicates survey area boundary.



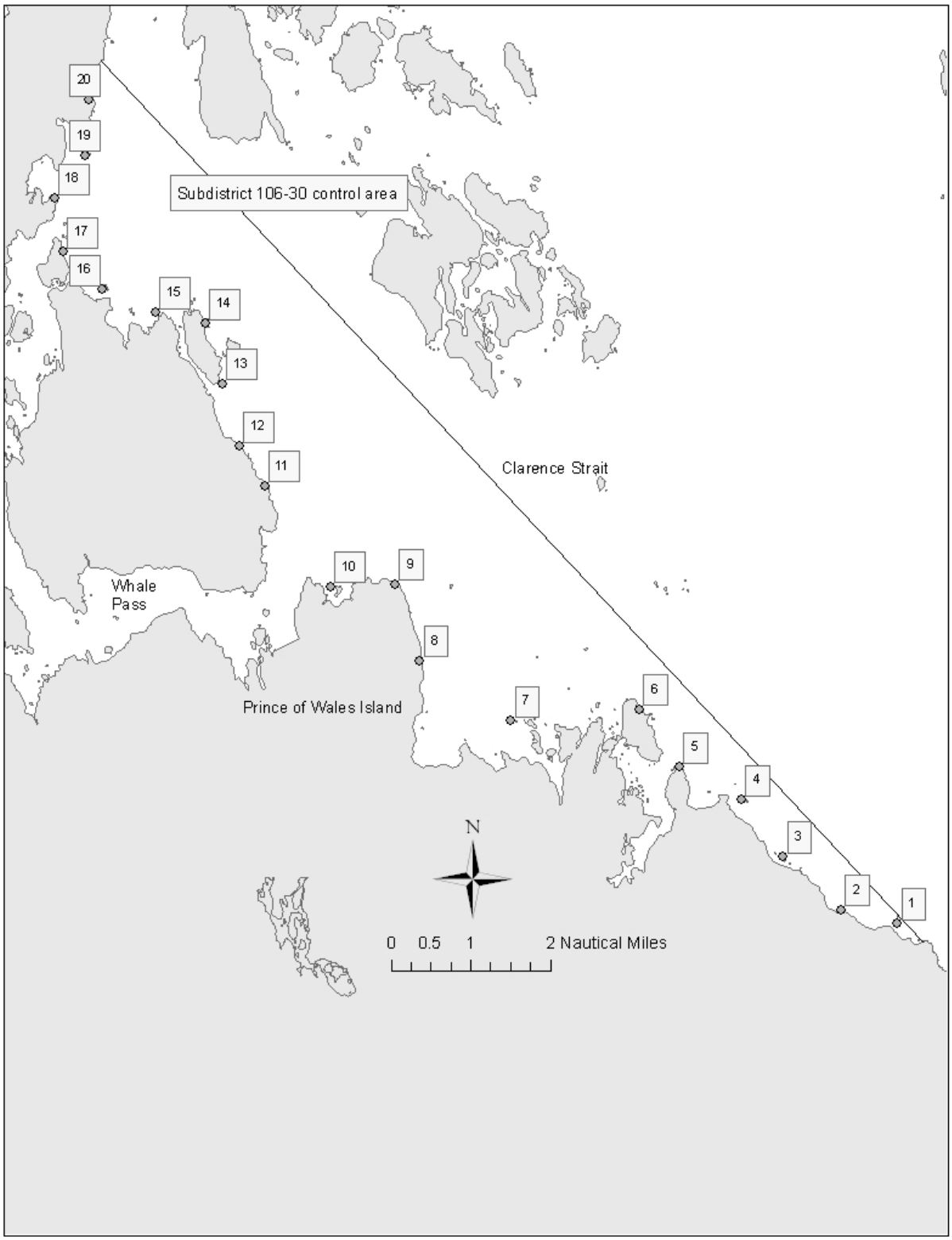
Appendix D2.–Location of transects for control area Subdistrict 103-40. Black line indicates survey area boundary.



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



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



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