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ABSTRACT

Beginning in 1999 selected invertebrates began to be systematically recorded in annual ecosystem trawl surveys of the Scotian Shelf. Originally designed for groundfish, the surveys from 1999-2006 have provided very useful data on a number of important benthic invertebrates. Over the period of 1999-2006 data were collected on the distribution and abundance of decapod species (lobsters, crabs, shrimp), scallop species and echinoderms. The decapod species (*Homarus americanus, Cancer borealis, Cancer irroratus, Chaceon quinquedens, Lithodes mya, Chionoecetes opilio, Hyas araneus, Hyas coarctatus, Pandalus montagui, Pandalus borealis*) had unique distributions with temperature and depth. Geographic distributions were corroborated from other sources where possible, but synoptic distribution data on the scale of the Scotian Shelf were only available through the ecosystem trawl surveys. The known distribution of several decapod species on the Scotian Shelf has expanded as a result of these surveys. Echinoderms (starfish, sea cucumbers, sea urchins and sand dollars) had among the highest frequencies and abundances and it would be of value to record this group at higher taxonomic resolution. Associated with this publication, discovery metadata have been created specifically for 'DFO Maritimes Research Vessel Trawl Surveys Invertebrate Observations'.

RÉSUMÉ

En 1999, on a commencé à consigner systématiquement des données sur certains invertébrés lors des relevés écosystémiques annuels au chalut effectués sur le plateau néo-écossais. Ces relevés visaient à l'origine le poisson de fond, toutefois, les relevés de 1999 à 2006 ont permis de recueillir des données très utiles sur un certain nombre d'invertébrés benthiques importants. Durant cette période, on a recueilli des données sur la distribution et l'abondance de certains décapodes (homards, crabes, crevettes), pétoncles et échinodermes. Les décapodes (*Homarus americanus, Cancer borealis, Cancer irroratus, Chaceon quinquedens, Lithodes mya, Chionoecetes opilio, Hyas araneus, yas coarctatus, Pandalus montagui, Pandalus borealis*) avaient des distributions uniques, en fonction de la température et de la profondeur. On a comparé les données sur les distributions géographiques avec celles d'autres sources chaque fois que cela était possible, mais seuls les relevés écosystémiques au chalut ont permis de recueillir des données sur la distribution synoptique à l'échelle du plateau néo-écossais. Ces relevés ont permis de constater que la distribution de plusieurs espèces de décapodes sur le plateau néo-écossais était plus étendue qu'on le pensait. C'est chez les échinodermes (étoiles de mer, concombres de mer, oursins et clypéastres) qu'on a relevé les plus hauts niveaux de fréquence et d'abondance, aussi, il serait bon de recueillir des données sur ce groupe à un niveau de résolution taxinomique plus élevé. Parallèlement à cette publication, on a constitué des métadonnées de découverte spécialement pour les observations sur les invertébrés découlant des relevés au chalut effectués par les navires de recherche du MPO, Région des Maritimes.

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INTRODUCTION

A stratified random trawl survey has been conducted on the Scotian Shelf (Fig. 1) every July since 1970 by the Department of Fisheries and Oceans. Originally designed for groundfish, these surveys collect a wide variety of other species and are now considered ecosystem surveys because of the increased range of fauna that are monitored, and because of the physical data collected.

Benthic invertebrates were reported inconsistently or not at all from 1970-1998. In 1999 an effort was initiated to regularly capture data on selected invertebrate taxa that are retained in the trawl. These taxa were lobster, several species of crab, scallops, and several groups of echinoderms. These taxa were selected because they occurred regularly in the trawl catch, they could be quantified accurately, and several had existing or potential commercial value.

In this report we review the records of the selected invertebrate taxa and present data on annual means and geographic distribution. We show that for some invertebrates, the trawl survey provides reliable distribution data, and could be used to develop indicators of distribution, and possibly coarse indicators of abundance.

METHODS

ECOSYSTEM SURVEYS

The ecosystem surveys forming the basis of this report are listed in Table 1. The trawl survey design is stratified random with the strata defined on the basis of depth. Samples of fish and invertebrates were obtained with a Western IIA bottom trawl towed for 30 minutes at a speed of 3.5 knots. The trawl has a 106 foot roller-rigged footrope and 2000 pound Portuguese doors. The codend is lined with ¾" mesh to retain smaller animals. For further details on standard methods used in the surveys refer to Koeller (1981). Bottom temperature was measured at all survey stations.

Vessels used for the survey were the Alfred Needler (1999-2003, 2005-2006) and the Teleost (2004, 2005). The Teleost was the sole vessel used in 2004 as the Needler was in repair; in 2005 both vessels were deployed and comparative tows were completed. In 2004 most of the invertebrates documented here had lower catch rates. This was due to lower gear selectivity resulting from the trawl net being rigged differently in that year. As such the time series data need to be interpreted with this in mind. In 2005 the trawls on both the Teleost and Needler were rigged in the manner of pre-2004 surveys and catch rates of the two vessels were not consistently different (Don Clark, pers. comm). No comparison is undertaken in this document, and all 2005 tows are included.

The ecosystem survey is run on a 24 hour basis. As such there are two watches or shifts: watch I is active from 0000-0600 hrs and 1200-1800 hrs; watch II is active from 0600-1200 hrs and 1800-0000 hrs. The survey is broken into two legs, each approximately two weeks in length. One leg covers the eastern portion of the shelf, the other the western portion. The scientific staff changes at the end of the first leg.

Up until 1999 lobsters and squid were the only invertebrates that were recorded with consistency. Historical trends in the total catch of these species is available in Clark and Perley (2006). Prior to 1999 many other invertebrate species were recorded, but only in some years. Beginning in 1999, selected invertebrates were recorded more systematically. In addition the individual sizes of some invertebrates were recorded for the first time. The shift to recording invertebrates in a systematic manner occurred over several years with the shift somewhat slower on the western portion of the survey. Although the increase in invertebrate data collection was substantial beginning in 1999, the invertebrate protocols were not consistently followed until 2005.

A manual was developed for identification and processing of selected taxa (Day and Tremblay 2000). Processing methods for invertebrates were as follows for the different groups. Note that weight measurements were recorded to the nearest 1/100th of a kg (10 gm) and all morphometric measurements were to the nearest mm.

I. All crabs (except hermit crabs) and lobsters

The total weight was determined for each species. Next individuals were counted, measured (in mm) and sexed (Males = 1, Female = 2, Female with eggs = 3). The size measurement for lobsters was the carapace length (CL); size measurement for crabs was the carapace width (CW). For the crabs, modified calipers equipped with ‘bars’ were provided to avoid variability associated with lateral spines. CW was taken as the maximum width including spines and rounded down to the nearest mm.

II. Shrimp (*Pandalus borealis* and *P. montagui*)

Two main species were recorded. For large mixed catches the total weight of both species was determined. Next a 1 kg subsample was taken and the two species were separated and weighed. The weight proportion of each species was used to estimate the total weight caught of each species in the trawl. Finally the total number of each species was estimated by counting the number of individuals in each subsample portion, determining mean individual weight and dividing into the total weight. For small catches (< 1 kg), the total count and total weight of each of the 2 species was determined

III. Bivalve molluscs – primarily scallops

For this group the total weight of each taxon was determined including live broken shells.

Clams and smaller bivalves were generally too broken up to separate and record. Intact scallops were counted and measured. For bivalves the size measurement was from the hinge to the outer rim.

IV. Others - Starfish, urchins, sand dollars, sea cucumbers, hermit crabs, other shrimps and octopods

For these taxa the total weight was determined and if there were fewer than 20-30 individuals, they were counted as well. Estimates of total count were made by counting the number in one basket and multiplying this by the number of baskets.

DATA PRESENTATION AND ANALYSIS

Numbers and weights per standard tow length along with associated tow data (temperature and depth) were extracted for each taxon from the ecosystem survey Oracle databases. All extractions and plots were done via the Virtual Data Centre (VDC). Associated with this publication, discovery metadata have been created specifically for 'DFO Maritimes Research Vessel Trawl Surveys Invertebrate Observations'. These metadata are provided in Appendix 1.

RESULTS

A large diversity of invertebrates was captured in the ecosystem trawl surveys over the period. The taxa documented here represent only a portion of what is retained by the trawl. Table 2 is a taxonomic list of the taxa reported here, including Integrated Taxonomic Information System (ITIS) Taxonomic Serial Numbers. Represented are six families of decapod crustacea, one family of bivalve molluscs and at least five families of echinoderms. Table 3 provides several metrics of the occurrence of these taxa in the ecosystem surveys. Total weights and total numbers were not recorded with the same frequency for all taxa, but we can make the following observations. The starfish and snow crab taxa were the first and second most frequently recorded by both weight and number. Looking only at positive sets, shrimp (*Pandalus borealis*) had the highest median weight per tow (4.1 kg), followed by lobster (3.5 kg). By number, both species of shrimp had the highest counts per tow by far (92,618 and 37, 410) followed by sea cucumbers (8985). Clearly echinoderms are an important component of the invertebrate catch.

In the following results we present figures for each taxon as follows:

1) the annual stratified mean number per tow (StratNo) and stratified mean weight per tow (StratWt) in kg from 1999-2006,

2) for those taxa that were measured, the size frequency of animals captured over the entire 8 year period, expressed as a percentage of the total,

3) line plots of the distribution by temperature interval and by depth interval,

4) distribution maps for each year and for all years combined.

With regard to the distribution maps, we display either the number per tow or the weight per tow as appropriate. For lobster, crabs and scallops, counts were generally recorded as often or more often than total weight (Table 3). As such for these taxa the distribution maps are of numbers per stratified tow. For the remaining taxa, the total weight per stratified tow is displayed. Note that no correction is made for the reduced catch of most invertebrates in 2004. If a correction was made, the metrics reported in Table 3 would increase.

DECAPOD CRUSTACEA

Decapod crustacea, particularly lobsters and crabs, was the group that was most readily quantified. They are generally easily identified, they come up in the trawl intact and their hard shell is readily measured. Below we discuss the results by species or taxonomic grouping.

Lobster - *Homarus americanus*

Lobsters were recorded in 20% of all sets during summer surveys (Table 3). The median number of lobster in positive sets was 2.9; the median weight was 3.5 kg. StratNo and StratWt tracked each other identically from 1999-2006 and in recent years (2005 and 2006) StratNo averaged 1.6, while StratWt averaged 2.2 kg (Fig. 2). A wide size range (31 to 218 mm carapace length) of lobsters was captured. Female lobsters had a modal carapace length (CL) approximately equal to 110 mm, and the percentage at size dropped rapidly above 120 mm CL (Fig. 3). Males were more evenly distributed with size, with a drop off beginning around 132 mm CL.

The temperature and depth distribution of all sets and of sets positive for lobster for the 1999-2006 surveys is shown in Fig. 4. In the summer survey the bottom temperature ranged from -1.0 to 14 ^{o}C, but 90% of all sets occurred at temperatures between 1 and 9 ^{o}C. Depths ranged from 22 m to 713 m but most sets were at depth of 50-200 m (Fig. 4). Bottom water temperature was an important determinant of lobster distribution but depth was not. Most positive sets coincided with bottom temperatures greater than 6 ^{o}C. The distribution of positive sets by depth was very similar to the distribution of all sets by depth, indicating no depth preference by lobsters (Fig. 4). Lobsters were captured primarily on the western half of the Scotian Shelf during the ecosystem surveys

(Fig. 5, 6). None were recorded east of the Gully (59 ^{o}W) and most of those captured east of 64 ^{o}W were on the slope. The individual year maps show that lobster were consistently captured in the same locations: the Bay of Fundy, Browns Bank and the Northeast Channel, with reduced numbers on the slope west of the Gully.

Jonah Crab – *Cancer borealis*

Jonah crab were recorded in 24% of all sets during summer surveys (Table 3). Compared to lobster, Jonah crab represented a much smaller fraction of the catch. The median number of Jonah crab in positive sets was 2.0; the median weight was 0.3 kg. As for lobster, Jonah crab StratNo and StratWt followed the same trend from 1999-2006 and in 2005-06 StratNo averaged 0.9, while StratWt averaged 0.2 kg (Fig. 7). Sizes of Jonah crab recorded ranged from about 10 mm to approximately 170 mm carapace width (CW), with most between 70 and 120 mm CW (Fig. 8). The recording of Jonah crab sex was not consistent enough and in fact only for lobster and snow crab were there sufficient data on males and females to plot size frequency by sex.

Jonah crab distribution was affected by both temperature and depth (Fig. 9). Like lobster, Jonah crab were more likely to be found in sets where the bottom temperature was warmer. Of the positive sets for Jonah, 84% were in temperatures greater than 5 ^{o}C compared to 55% for all sets. Jonah crab were over-represented in sets between 100 and 200 m (Fig. 9).

Jonah crab were found mainly on the western half of the Scotian Shelf (Fig. 10, 11). A few were recorded east of the Gully on Banquereau, but none were recorded on the inner portion of the eastern Scotian Shelf.

Rock Crab – *Cancer irroratus*

Rock crab were collected in just 9% of all sets during summer surveys (Table 3) but when they did occur they tended to be as abundant as their congeneric (Jonah crab). The median number of rock crab in positive sets was 2.1; the median weight was 0.2 kg. The lower weight reflects the smaller size of rock crab relative to Jonah. Rock crab StratNo and StratWt trended similarly although StratNo peaked in 2000, whereas StratWt was highest in 2005 and 2006 (Fig. 12). In recent years rock crab StratNo averaged 0.7, while StratWt averaged 0.06 kg (Fig. 12). Sizes of rock crab recorded ranged from about 10 mm to approximately 145 mm carapace width, with most between 60 and 100 mm CW (Fig. 13).

Rock crab were restricted mainly to the shallower depths sampled by the ecosystem survey (Fig. 14). Of the positive sets, 86% were in depths less than 150 m while only 45% of all sets were in this depth range. With regard to temperature, rock crab were under-represented in sets where temperatures were

less than 8 ^{o}C. Rock crab were consistently collected in five main areas: Sable Island Bank, Middle Bank, Browns Bank, the Bay of Fundy and outer St. Mary's Bay (Fig. 15, 16).

Red Crab – *Chaceon quinquedens*

Of the crabs considered here, red crab was the rarest, with records in just 2% of the sets from 1999-2006 (Table 3). The median number of red crab in positive sets was 2.1; the median weight was 0.4 kg. StratNo and StratWt trended similarly over the period and in 2005-06 StratNo averaged 0.3, while StratWt averaged 0.06 kg (Fig. 17). Sizes of red crab recorded ranged from 38 mm to 143 mm carapace width although one individual was recorded at 195 mm CW (Fig. 18). The percentage of positive sets for red crab was highest at 4 ^{o}C, and no red crab were found below 2 ^{o}C (Fig. 19). A second peak in occurrence of positive sets occurred at a temperature of 8 ^{o}C. With regard to depth, the highest percentage of positive sets was at a depth of 550 m, but a few red crab were found at depths of 50-100 m (Fig. 19). As might be expected from their distribution with temperature and depth, red crab were restricted to the outer slope of the Scotian Shelf and the Fundian Channel (Fig. 20, 21).

Northern Stone Crab – *Lithodes maya*

Northern stone crab were recorded in 11% of the sets from 1999-2006 (Table 3). The median number of stone crab in positive sets was 2.0; the median weight was 0.5 kg. StratNo and StratWt trended the same over the period and in 2005-06 StratNo averaged 0.3, while StratWt averaged 0.07 kg (Fig. 22). Sizes of northern stone crab recorded ranged from 14 mm to 155 mm carapace width (Fig. 23). Positive sets for Northern stone crab were associated with temperatures of 4-8 ^{o}C, and depths of greater than 100 m (Fig. 24). This combination of temperature and depth was found primarily along the edge of the Laurentian Channel and the eastern Scotian Shelf to the Gully, on the western Scotian Shelf on the sides of banks such as Roseway Bank, and in the mouth of the Bay of Fundy (Fig. 25, 26). Stone crab were consistently recorded in these locations over the years.

Snow Crab - *Chionoecetes opilio*

Snow crab were the most frequently recorded crab in the summer ecosystem surveys, occurring in 38% of all sets from 1999-2006 (Table 3). The median number of snow crab in positive sets was 10.4; the median weight was 1.6 kg. StratNo and StratWt tracked each other over the period and in the last two years StratNo averaged 13.8 and StratWt averaged 1.3 (Fig. 27). A wide size range of snow crabs was recorded (5 to 150 mm CW) (Fig. 28). All females were less than 80 mm CW. Positive sets for snow crabs were closely linked with lower temperatures. Of the positive sets, 62% were in temperatures less than 4 ^{o}C and 92% were in temperatures less than 7 ^{o}C (Fig. 29). With regard to depth, snow

crab positive sets were distributed in proportion to all sets, indicating no depth preference. Snow crab were most abundant on the eastern Scotian Shelf but were found in lower numbers as far west as Browns Bank (Fig. 30, 31). There were two rare records in the outer Bay of Fundy in 2002 (Fig. 30).

Toad Crab and Lyre crab – *Hyas araneus* and *Hyas coarctatus*

These congeneric species are considered together because they may be mistaken for one another, particularly at smaller sizes. The carapace of the lyre crab, also known as the lesser toad crab (Pohle 1990) is more dilated laterally but some individuals seem to be intermediate in shape to the two species. Other characteristics (e.g. rostral horn features) can also be used to distinguish these species, but even these do not provide for unambiguous identification of all specimens (MJT, personal observation).

There was some inconsistency in the distribution over years for both species (see below). It may be that different identifiers coded these species inconsistently over the years.

Hyas araneus were recorded in 14% of all sets during summer surveys (Table 3). The median number of toad crab in positive sets was 2.0; the median weight was 0.1 kg. StratNo and StratWt trended similarly and in 2005-2006 StratNo averaged 0.6 and StratWt averaged 0.07 kg (Fig. 32). Sizes of toad crab recorded ranged from 5 mm to approximately 110 mm carapace width (Fig. 33). The smallest size records are questionable given the challenge of distinguishing the two Hyas species, particularly at small sizes. Positive sets for toad crab coincided with temperatures of 0-9 ^{o}C, but the bulk of the positive sets (75%) were in temperatures less than 7 ^{o}C (Fig. 34). With regard to depth, 87% of positive sets for toad crab were at depths less than 100 m. Toad crab were found over much of the Scotian Shelf, but in the west were mainly on Browns Bank and the Bay of Fundy (Fig. 35, 36).

Lyre crab were recorded at modestly higher levels than toad crab. Lyre crab were recorded in 16% of all sets with a median number of 3.0 in positive sets and a median weight of 0.2 kg (Table 3). In recent years StratNo averaged 2.5 and StratWt averaged 0.13 kg (Fig. 37). Sizes ranged from less than 5 mm to 92 mm carapace width (Fig. 38). Again there is a caveat about the identification of the smaller sizes. Lyre crab were more associated with lower temperatures than toad crab, with 91% of positive sets in temperatures less than 7 ^{o}C (Fig. 39). Lyre crab were predominantly in shallow waters but tended to be a little deeper than toad crab with 72% of positive sets at depths less than 100 m (Fig. 39). The distribution of Lyre crab was quite similar to that of toad crab (Fig. 40, 41).

Northern Shrimp and Striped Shrimp - *Pandalus borealis* and *Pandalus montagui*

Of the invertebrates recorded in the trawl surveys, shrimp were by far the most numerous. Northern shrimp were collected in 16% of all sets during summer surveys (Table 3). The median number of northern shrimp in positive sets was 833; the median weight was 4.1 kg (Table 3). In 2005-2006 the StratNo of Northern shrimp averaged 2075 and the StratWt averaged 12.1 kg (Fig. 42). Positive sets for Northern shrimp tended to be associated with temperatures less than 6 ^{o}C and depths from 50 to 350 m (Fig. 43). Over the period *P. borealis* were reported primarily from the eastern Scotian Shelf, mainly inside of Banquereau and Sable Island Banks and along the Laurentian Channel (Fig. 44, 45). A few were recorded on the western Scotian Shelf and in the Bay of Fundy.

Striped shrimp were more widespread than northern shrimp but were less abundant overall. P. montagui was recorded in 22% of all sets during summer surveys (Table 3). The median number of striped shrimp in positive sets was 213; the median weight was 0.6 kg (Table 3). In 2005-2006 the StratNo of Striped shrimp averaged 487 and the StratWt averaged 1.1 kg (Fig. 46). Positive sets for striped shrimp were found over the full range of temperatures sampled by the summer ecosystem survey but tended to be shallower than northern shrimp, with few positive sets deeper than 200 m (Fig. 47). Striped shrimp were found over much of the Scotian Shelf and Bay of Fundy but were largely absent from the outer eastern banks (Banquereau and Sable Island) (Fig. 48, 49).

OTHER TAXA

SCALLOPS

Sea scallop - *Placopecten magellanicus*

Sea scallops occurred in 17% of the sets from 1999-2006 (Table 3). The median number of sea scallops in positive sets was 3.0; the median weight was 0.5 kg. StratNo and StratWt trended similarly, and in 2005-2006 StratNo averaged 1.5 and StratWt averaged 0.16 kg (Fig. 50). Sizes of sea scallop recorded ranged from 16 mm to 164 mm in shell height (Fig. 51). Sea scallop positive sets were associated with temperatures greater than 2 ^{o}C and depths of 150 m and less (Fig. 52). There were three main areas where sea scallops were recorded consistently over the years: the Sable Island-Western Banks, Browns Bank and the Bay of Fundy, including the approaches (Fig. 53, 54).

Iceland scallop – *Chlamys islandica*

Iceland scallops occurred in 9% of the sets from 1999-2006 (Table 3). The median number of Iceland scallops in positive sets was 2.7; the median weight was 0.1 kg. StratNo for Iceland scallops averaged 0.7 in 2005-2006 and StraWt averaged 0.06 kg (Fig. 55). Recorded sizes ranged from 17 mm to 110 mm in

shell height (Fig. 56). Iceland scallop positive sets were associated with lower temperatures than sea scallops with more than 90% of positive sets associated with temperatures less than 5 ^{o}C (Fig. 57). Iceland scallops also tended be shallow, with more than 90% of positive sets in depths of 150 m and less (Fig. 57). These temperature and depth conditions translated into a distribution on the eastern Scotian Shelf, particularly on Sable Island and Banquereau Banks (Fig. 58, 59).

ECHINODERMS

Starfish – Asteroidea

In the ecosystem surveys, the starfish taxon is synonymous with the class Asteroidea and as such is a broad taxonomic group. Class Ophiuroidea (brittle stars and basket stars) were generally not recorded.

Recorded in the Asteroidea taxon were the common sea stars *Asterias* sp. (*A. rubens* and possibly *A. forbesii*), sunstars (e.g. *Solaster endeca*, *Crossaster papposus, Lophaster furcifer*) and blood stars (*Henricia sanguinolenta*). Six other species within the Asteroidea that were identified during the ecosystem surveys are listed in Table 2.

Starfish were the most common invertebrate taxon recorded, occurring in 64% of the sets from 1999-2006 (Table 3). Part of this no doubt relates to the fact that this taxon comprises several species. The median number of starfish in positive sets was 7.6; the median weight was 0.3 kg. Starfish StratNo and StratWt trended similarly from 2000-2006 (Fig. 60). In 2005-2006 StratNo averaged 8.8, while StratWt averaged 0.6 kg. This large group occurred over a broad range of temperatures, but the proportion of positive sets was higher at lower temperatures (Fig. 61). Starfish were found at all depths (Fig. 61) with no apparent preference. Starfish are found over the entire Scotian but were recorded mainly on the eastern half. In the west starfish were recorded in the Bay of Fundy and on Browns Bank (Fig. 63).

Sea cucumbers – Holothuroidea

Most of this category was comprised of the common orange-footed cucumber *Cucumaria frondosa*, but there other species of sea cucumber on the Scotian Shelf (Gosner, 1978). These include the Silky cucumber (*Chiridata laevis),* the rat-tailed cucumber (*Caudina arenata*) and the Scarlet Psolus (*Psolus fabricii)*.

Sea cucumber occurred in 26% of the sets from 1999-2006 (Table 3). The median number of sea cucumber in positive sets was 4.0; the median weight was 1.9 kg. StratNo and StratWt did not trend the same over the period, likely because count was recorded less frequently than weight. Sea cucumber StratNo averaged 1.6 in 2005-2006 and StratWt averaged 7.0 kg (Fig. 64). Sea cucumber

positive sets were associated with temperatures less than 6 ^{o}C and depths less than 150 m (Fig. 64). It appears that in 1999 and 2000 sea cucumbers were not recorded at all during the western portion of the survey (Fig. 66). Later surveys show that sea cucumber are found mainly on the eastern Scotian Shelf, but are also found on LaHave, Roseway and Browns banks, and to a lesser extent in the Bay of Fundy (Fig. 66, 67).

Sand dollars - *Echinarachnius parma*

Sand dollars *Echinarachnius parma* were the least prevalent of the echinoderm taxa, with records in 19% of the sets from 1999-2006 with (Table 3). The median number of sand dollars in positive sets was 2.9; the median weight was 0.1 kg. StratNo and StratWt for sand dollars had similar trends over the period. In 2005-2006, StratNo averaged 0.9 and StratWt averaged 0.06 kg (Fig. 68). Positive sets for sand dollars were associated with temperatures below 6 ^{o}C and depths less than 150 m (Fig. 69). It appears that sand dollars are more prevalent on the eastern banks, particularly Banquereau (Fig. 70, 71). Sand dollars were largely absent from the western shelf with the exception of a few positive sets in the upper Bay of Fundy in 2003, 2005 and 2006.

Sea urchins - *Strongylocentrotus droebachiensis*

The only sea urchin recorded during the ecosystem survey was the green sea urchin (*Strongylocentrotus droebachiensis*) but the purple sea urchin (*Arabacia puntulata*), a more southern species, may have been encountered as well.

Sea urchins were recorded in 30% of the sets from 1999-2006 (Table 3). The median number of sea urchins in positive sets was 10.0; the median weight was 0.7 kg. StratNo and StratWt trended somewhat differently except for the last two years (Fig. 72). In 2005-2006, StratNo averaged 5.2 and StratWt averaged 0.6 kg (Fig. 72). Sea urchins tended to be associated with temperatures less than 6 ^{o}C, and depths less than 150 m (Fig. 73). Most sea urchins were recorded on the eastern Scotian shelf, but there were records in the inner half of the Bay of Fundy (Fig. 74, 75).

COMPARISON OF CATCH OF DIFFERENT WATCHES

A visual comparison of the average number per watch for some of the taxa for the different survey legs is presented in Fig. 76-77. Lobster can be used as a basis of comparison, since this species is expected to have been consistently identified and recorded on both watches. In some instances the number of lobsters per tow on one watch was 50% higher than the other watch (e.g. NED 1999925).

With regard to those taxa that were consistently counted and weighed (decapods and sea scallops), if taxa were recorded on one watch they were generally

recorded on the other watch as well. Ignoring means less than about 0.5 per tow (taxa in low abundance may have only been collected on one watch by chance), most of the exceptions to the above statement involved toad crabs e.g. Lyre crab (NED 1999925), and Toad crab (NED 2001032, 2001037, 2004530). Rock crab was also recorded on only one watch on two legs (NED 2001037 and 2003042). Rock crab may at times have been recorded as Jonah crab, which was recorded on each watch in each survey.

With regard to the echinoderm taxa that were weighed but not always counted, there was little indication of an important difference between watches. Sea cucumbers may have been under-recorded on one watch on NED2004026 but for the most part the variation between watches is what might be expected.

DISCUSSION

The report shows that the survey provides very useful data for several invertebrate taxa. With the exception of toad crabs, and to a lesser extent rock crab, the decapod crustacea appear to have been reliably recorded for the most part. The distribution patterns of the different decapod species are quite unique during summer. While they overlap, the lobster, crab and shrimp species differ in their distributions with temperature and depth. Some taxa are found predominantly in cold water (< 6 ^{o}C) (snow crab, northern shrimp and lyre crab) while others are found mainly in the warmer waters of the Scotian Shelf (Jonah crab and lobster). The distribution of other species is more linked to depth, either shallow (< 100 m, rock crab) or deep (200-600 m, red crab). A more detailed analysis of species-specific temperature and depth preferences will be the subject of a separate publication.

For some of the other invertebrate taxa, this report documents that they can be significant in terms of number and weight per tow. Echinoderm taxa were among the most frequent and abundant invertebrates observed in the trawl.

Below we discuss the distribution of the different taxa in relation to other studies and comment on some of the annual variability seen in the surveys.

DECAPOD CRUSTACEA

The invertebrate protocols were new in 1999, and science survey personnel had different levels of expertise. Given that crews differed between survey legs and watches, it is understood that the level of data recording might be uneven across different crews. Personnel who were knowledgeable in the invertebrate protocols participated in most of the summer surveys from 1999 onwards but they were not on each watch. Our examination of the data collected over the years gives us confidence that most of decapods were recorded correctly most of the time. The spatial plots of distribution for nearly all of the decapod and scallop species showed year to year consistency in where the species were captured.

Examination of the distribution of several of the decapod species and comparison with other sources of distribution data gives further confidence that these species were recorded satisfactorily.

With regard to lobsters, Fig. 5 and 6 capture an important portion of the distribution of this species on the Scotian Shelf although of course they do not capture the large biomass of lobsters closer to shore where the trawl survey does not venture. The number of lobster caught per tow was low but comparable to that obtained for the Gulf of Maine during trawl surveys conducted by the National Marine Fisheries Service. Used in the U.S. lobster stock assessment by the Atlantic States Marine Fisheries Commission (ASMFC) as a fishery independent index of abundance, the number of lobsters per tow ranged from approximately 1.9 to 4.2 per tow (legals and sublegals combined) from 1999 to 2003 (Fig. 5.3.2.1 in ASMFC 2006). The stratified mean number per tow in the Canadian summer ecosystem survey was about 1.6 in recent years (Fig. 3); if we consider only the western portion of the survey where most lobsters are caught in the survey (NAFO Division 4X , west of 63 20') the number of lobsters per tow over the period from 1999-2006 would be greater than 4, very similar to was is documented in the U.S. trawl surveys. The Scotian Shelf ecosystem survey may prove useful as a coarse indicator for the abundance of lobsters and other decapods where there are no fishery-independent data available. Caution would need to be used in interpreting some of the annual differences in mean number per tow, particularly when they are coincident with major changes in gear or vessels e.g. 2004 when the net was rigged differently resulting in different gear selectivity.

The distribution of Jonah crab illustrated in (Fig. 10, 11) includes the area where the directed fisheries takes place in LFAs 33 (Adams et al. 2000), LFAs 34-38 (Robichaud and Frail, 2006) and the offshore (Robichaud et al. 2000). Fig. 10 and 11 also illustrate that Jonah crab are found further to the east than where most commercial fishing has occurred. As recently as the 1980's Squires (1990) reported a distribution range for Jonah crab of Grand Banks to Florida but shows only two records on the Scotian Shelf east of 64 ^{o}W (La Have Bank) and both records were are on the slope. The ecosystem survey demonstrates that Jonah crab are distributed much more extensively on the Scotian Shelf than was previously thought.

The distribution of rock crab (Fig. 15, 16) is of particular interest. There is an inshore fishery for rock crab in coastal Nova Scotia including the Bay of Fundy (Tremblay and Reeves 2000, Robichaud and Frail, 2006), and the Bay of Fundy aggregation is clearly depicted in Fig. 15 and 16. Because the ecosystem survey does not cover the nearshore it did not detect the stocks all along the Atlantic coast of Nova Scotia but the ecosystem survey did detect a rock crab aggregation on Sable Island Bank and Middle Bank. This "stock" can be considered a virgin population in that it has not been commercially fished. Squires (1990) reports no offshore aggregations of rock crab.

The distribution of red crab (Fig. 20, 21) matches where the small Canadian fishery has been prosecuted (Duggan and Lawton 1996). Fig. 20 and 21 provide the same picture as that in Squires (1990). Red crab is at the northern limits of its distribution and has been pulse-fished by a small number of licenses with peak landings in 1996.

Stone crab have a distinct distribution along the edge of the Laurentian Channel and in patches on the western Scotian Shelf (Fig. 25, 26). Stone crab distribution continues north into the Laurentian Channel and Esquiman Channel, generally deeper than 300 m (DFO, 1998). The distribution map in Squires (1990) has only one record on the Scotian Shelf, close to the Gully. The distribution of stone crab from the ecosystem surveys on the Scotian Shelf was quite consistent from 1999-2006. Stone crab had a low mean number per tow, on the same order as red crab yet stone crab was more widely distributed. This crab has been the target of a number of experimental fisheries, and they have been captured as a bycatch in the 4X snow crab fishery. Although this large crab with long legs has good market potential, the experimental fisheries have not been successful in obtaining high catch rates compared to say snow crab. The low abundance in the ecosystem survey suggests that obtaining commercial catch rates for this species will be a challenge.

Snow crab was by far the most abundant large decapod recorded during the ecosystem survey (Fig. 30, 31). This species supports the largest decapod fishery on the eastern Scotian Shelf. Snow crab on the eastern Scotian Shelf supported landings as high as 10800 tons in 2003; more recent landings (2005) were on the order of 7000 tons.

While the summer ecosystem survey may give an indicator of snow crab abundance and distribution, the catchability of snow crab is much higher in the directed snow crab survey, which uses a Nephrops trawl that digs into the sediment. In the 2003 directed snow crab survey, the mean was 50.8 snow crab per set (8034 crab in 158 sets) (Biron et al. 2004). By contrast the 2003 summer survey had an unstratified mean of 9 per set (2008 crab in 222 sets). If only those trawls on the eastern part of the shelf (4VW) are considered the unstratified mean rises to 15 per set (1980 snow crab in 132 sets), still less than 1/3rd that of the directed snow crab survey. Catchability of snow crab in the Nephrops trawl is even greater when the much shorter tow length is considered. In the snow crab survey Nephrops trawl tows are typically 5 minutes in length at 2 knots (mean length 0.17 nautical miles or about 0.3 km) versus the Western IIa tows of 30 minutes at 3.5 knots (about 3.2 km). This rough comparison would indicate that the Nephrops survey is on the order of 35 times more efficient than the summer ecosystem survey at catching snow crab. For snow crab and other benthic invertebrates in the ecosystem survey, observations indicate that many were captured in the belly of the trawl as it drags across the bottom. As such the numbers captured are semi-quantitative, and dependent to some extent on what else is captured in the trawl.

As for toad crab and Lyre crab, there is not much distribution data to compare with the ecosystem survey distribution (Fig. 35, 36, 40, 41). Fishery data are limited to that from small experimental fisheries (for both species combined) in Sydney Bight (DFO, 1996). The distribution of the two species based on the ecosystem survey is quite similar and this may in part be due to confusion in identification. When using data for these species collected during the ecosystem survey, smaller sizes in particular should be considered as *Hyas* sp. because of the difficulty in distinguishing the two species.

The composite map of *Pandalus borealis* distribution in the ecosystem surveys (Fig. 45) fits well with what is known about the distribution of this species. Koeller (2005 – Fig. 1) identifies four major fishing locations on the eastern Scotian Shelf: the Missaine Hole, the Canso Hole, the Louisbourg Hole and the inshore area known as The Noodles. Each of these areas had high catches in the ecosystem survey (Fig. 45), indicating the ecosystem survey is tracking these aggregations. *Pandalus montagui* shows a more widespread distribution (Fig. 49) and the ecosystem survey provides the first composite picture of the distribution of this non-commercial species on the Scotian Shelf (P. Koeller, pers. comm.). Koeller (2000) reported that the data on pandalid shrimp from the ecosystem survey from 1970-84 seemed to match existing and historical shrimp fisheries; with the more precise data on the two species of *Pandalus*, such depictions are more useful.

SCALLOPS, ECHINODERMS AND OTHER SPECIES

The distribution of the sea scallop in the ecosystem surveys (Fig. 54) agrees well with what is know of their distribution from other sources. Black et al. (1993) identify the following fishing grounds on the Scotian Shelf: Bay of Fundy, Lurcher Shoals, Browns Bank, Sable Island Bank-Western Bank, Middle Bank and Banquereau Bank. As for the distribution of Iceland scallop (Fig. 59) this species is fished primarily on the Newfoundland shelf and is known to be restricted to the eastern part of the Scotian Shelf.

The echinoderms clearly comprise a substantial fraction of the catch in the ecosystem surveys. Starfish and sea cucumbers were among the most common and abundant invertebrates recorded. An identification manual could be developed so that most of the echinoderms could be reliably identified to species.

Other invertebrate species that are recorded during the ecosystem surveys but not discussed here were less common and in lower abundance. These include some species of crabs (hermit crabs, galatheid crabs) as well as octopods. The ecosystem survey should continue to record these taxa in anticipation of future interest, and taxonomic guides should be encouraged.

CONCLUSIONS

The ecosystem survey from 1999-2006 has provided very useful data on a number of important benthic invertebrates. Distribution maps and relationships with temperature and depth are now available that would be difficult to obtain any other way. There are fishery independent surveys for scallops, snow crab and shrimp, but none of these surveys covers the entire Scotian Shelf. For several decapod species, the documented range of distribution on the Scotian Shelf has expanded considerably as a result of the survey.

For species that are largely unfished, the ecosystem survey provides one of the few data sources. With the major changes in the Scotian Shelf ecosystem over the last 30 years (Choi et al. 2005, Frank et al. 2005), it would have been very interesting to have a time series of the abundance of the invertebrate component of the benthic ecosystem. Echinoderms in particular are a group that has been largely overlooked. In the future the ecosystem survey should provide a more comprehensive picture of the benthic ecosystem from about 2000 onwards. If echinoderms and other groups can be recorded at higher taxonomic resolution, the data from the surveys will be of more value for ecosystem indicators and modeling.

Applications of the data collected during the surveys to date have included providing advice on new fisheries and on the effects of oil and gas development. Since 2000 the data collected during the surveys on Jonah crab, stone crab, toad crab and sea cucumber have been very useful in advising on where to conduct exploratory fishing. In 2001 the data formed part of an overview for a review of oil and gas development off Cape Breton (Tremblay et al. 2001) and the data were used on an ad-hoc basis for reviews related to exploration on the outer Scotian Shelf. In the future the survey has the potential to provide the basis for more comprehensive ecosystem indicators and for some species, coarse level indicators of abundance.

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Table 1. Number of sets by year and vessel for summer ecosystem surveys, 1999-2006. The additional Teleost sets in 2005 were undertaken to compare catch rates with the Needler. Catch rates of the two vessels were similar and the comparison is not reported on here.

Year	Needler	Teleost	Total
1999	196		196
2000	219		219
2001	207		207
2002	214		214
2003	222		222
2004		192	192
2005	219	185	404
2006	215		215
Total	1492	377	1869

Table 2. Taxonomic listing of taxa recorded in the ecosystem survey and documented in this report. The most common level of identification during the ecosystem surveys from 1999-2006 is indicated by bold font. Integrated Taxonomic Information System (ITIS) Taxonomic Serial Numbers (TSN) are given in brackets and linked to www.itis.gov where appropriate.

Phylum Arthropoda, Subphylum Crustacea
- Class Malacostraca
  - Order Decapoda
    - Family Nephropidae
      - ***Homarus americanus*** **– American lobster** (97314)
    - Family Cancridae
      - ***Cancer borealis*****- Jonah crab** (98678)
      - ***Cancer irroratus*****- Rock crab** (98679)
    - Family Geryonidae
      - ***Chaceon quinquedens*** **– Deepsea red crab** (620992)
    - Family Lithodidae
      - ***Lithodes maja*** **– Northern Stone crab** (97943)
    - Family Oregoniidae
      - ***Chionoecetes opilio*** **– Snow crab** (98428)
      - ***Hyas araneus*****- Toad crab** (98426)
      - ***Hyas coarctatus*****- Lyre crab** (98423)
    - Family Pandalidae
      - ***Pandalus borealis*** **– Northern shrimp** (96967)
      - ***Pandalus montagui*** **– Striped pink shrimp** (96971)

Phylum Mollusca
- Class Bivalvia
  - Order Ostreioda
    - Family Pectinidae
      - ***Placopecten magellanicus*** **– Sea scallop** (79718)
      - ***Chlamys islandica*** **– Iceland scallop** (79619)

Table 2. Continued

Phylum Echinodermata
- Class Echinoidea (heart urchins, sand dollars, and sea urchins)
  - Order Clypeasteroida
    - Family Echinarachniidae
      - ***Echinarachnius parma* – Sand dollar** (158016)
  - Order Echinoida
    - Family Strongylocentrotidae
      - ***Strongylocentrotus droebachiensis* – Green sea urchin** (157969)

- **Class Holothuroidea - sea cucumbers** (158140)

- **Class Asteroidea – Starfish, Sea Stars** (156862)
  - Order Forcipulatida
    - Family Asteriidae
      - *Asterias sp.* (157215)
      - *Asteris rubens* (157220)
      - *Leptasterias polaris* (157240)
  - Order Spinulosida
    - Family Solasteridae
      - *Crossaster papposus*- spiny sun star, common sun star (157066)
      - *Solaster endeca* – Sun star (157076)
      - *Lophaster furcifer* (157071)
    - Family Echinasteridae
      - *Henricia sanguinolenta* – Blood Star (157165)
    - Family Pterasterida
      - *Pteraster militaris* (157109)
  - Order Paxillosida
    - Family Astropectinidae
      - *Leptychaster arcticus* (156890)
      - *Psilaster andromeda* (156898)
    - Family Goniopectinidae
      - *Ctenodiscus crispatus* – Mud Star (156940)
  - Order Valvatida
    - Family Goniasteridae
      - *Hippasterias phrygiana* (157008)
      - *Pseudoarchaster parelli* (157017)

Table 3. Counts and weights of selected taxa in 1869 sets of the summer survey 1999-2006. Shown is the occurrence (sets with a record of the taxon), the median and maximum (max) number per standard tow and the median and maximum weight per standard tow. Medians are based on positive sets only. The occurrence columns differ for Number and Weight because these two measures were not completed on all sets.

Taxon	Number			Weight (kg)		
		Number per standard tow			kg per standard tow	
	Occurrence No of sets (%)	Median	Max	Occurrence No of sets (%)	Median	Max
Homarus americanus	362 (19)	2.9	392	366 (20)	3.5	266
Cancer borealis	441 (24)	2.0	42	432 (23)	0.3	26
Cancer irroratus	175 (9)	2.1	72	177 (9)	0.2	9
Chaceon quinquedens	39 (2)	2.1	29	39 (2)	0.4	7
Lithodes mya	214 (11)	2.0	14	212 (11)	0.5	9
Chionoecetes opilio	711 (38)	10.4	289	695 (37)	1.6	39
Hyas araneus	259 (14)	2.0	140	201 (11)	0.1	29
Hyas coarctatus	293 (16)	3.0	316	258 (14)	0.2	9
Pandalus borealis	254 (14)	833.4	92618	297 (16)	4.1	540
Pandalus montagui	420 (22)	213.4	37410	462 (25)	0.6	120
Placopecten magellanicus	322 (17)	3.0	808	326 (17)	0.5	43
Chlamys islandica	168 (9)	2.7	113	170 (9)	0.1	12
Asteroidea	938 (50)	7.6	1784	1187 (64)	0.3	227
Sea cucumbers	333 (18)	4.0	8985	477 (26)	1.9	1924
Echinarachnius parma	316 (17)	2.9	99	364 (19)	0.1	7
Strongylocentrotus droebachiensis	395 (21)	10.0	1034	555 (30)	0.7	60

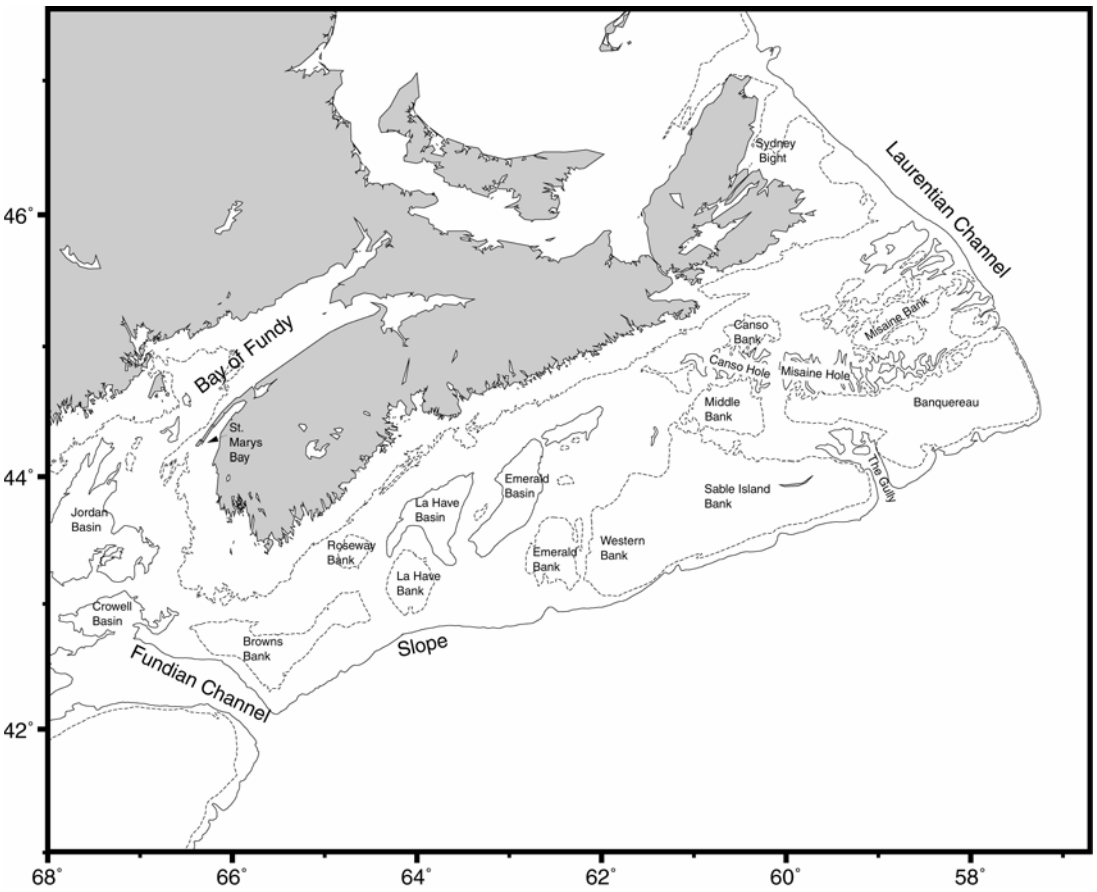

Fig 1. Map of Scotian Shelf and Bay of Fundy with place names mentioned in text. Depth contours shown are 200 m and 100 m (dashed line)

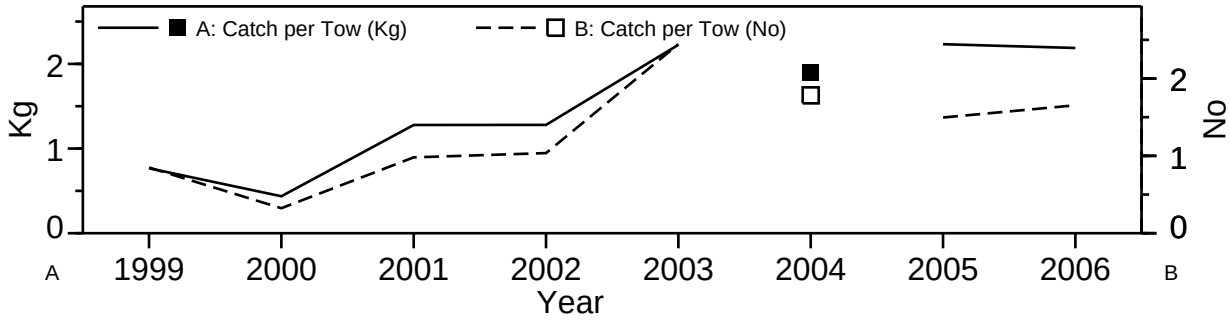

Fig. 2. American Lobster stratified mean weight caught per tow, stratified mean number caught per tow from the Summer Ecosystem surveys. The catch for 2004 was sampled using the MV Teleost. It has not been calibrated, and should not be compared to the earlier time series.

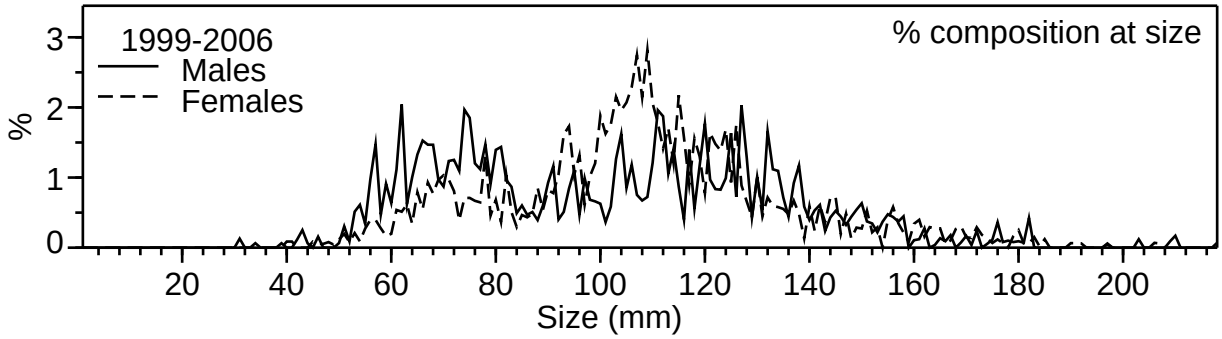

Fig. 3. American Lobster size frequency distribution from the Summer Ecosystem surveys.

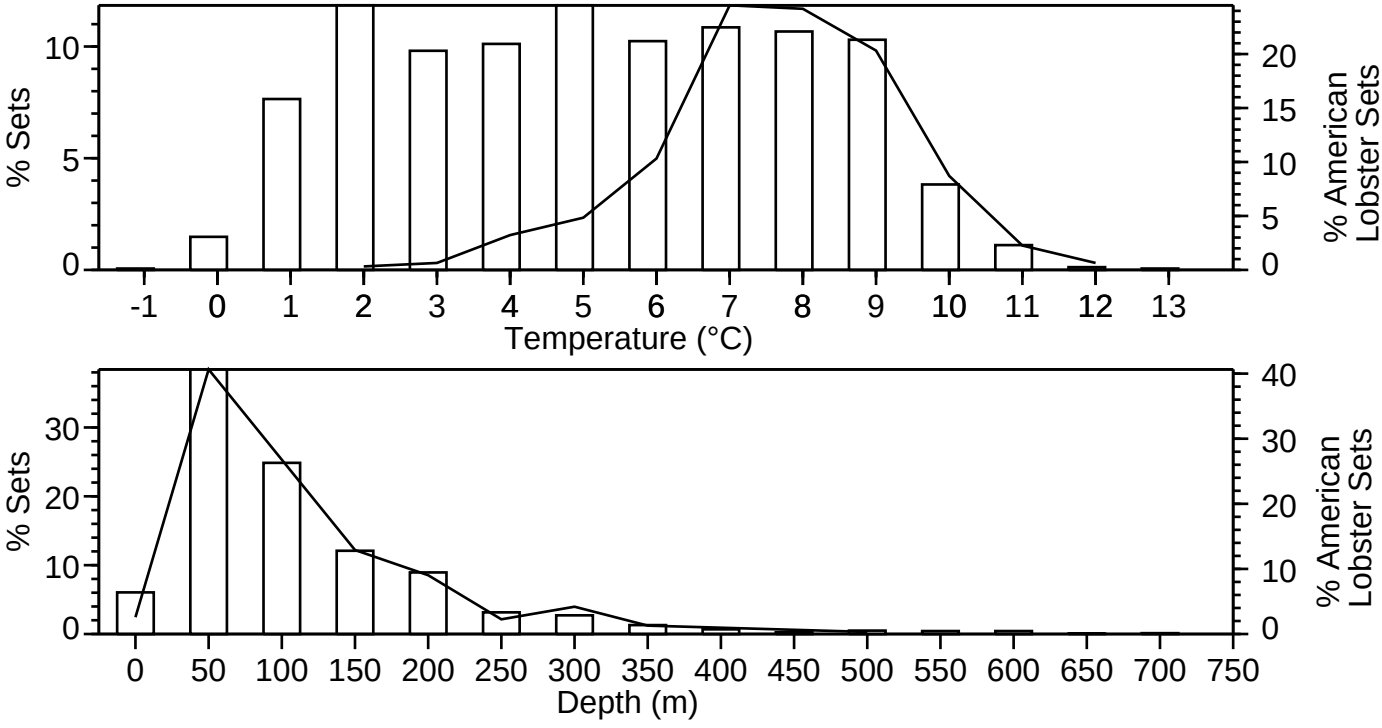

Fig. 4. Temperature and depth distribution of American Lobster captured from the Summer Ecosystem surveys 1999-2006. Shown for each variable is percentage of sets with American Lobster within given temperature or depth intervals (line) and percentage of all sets within different temperature or depth intervals (bar graph).

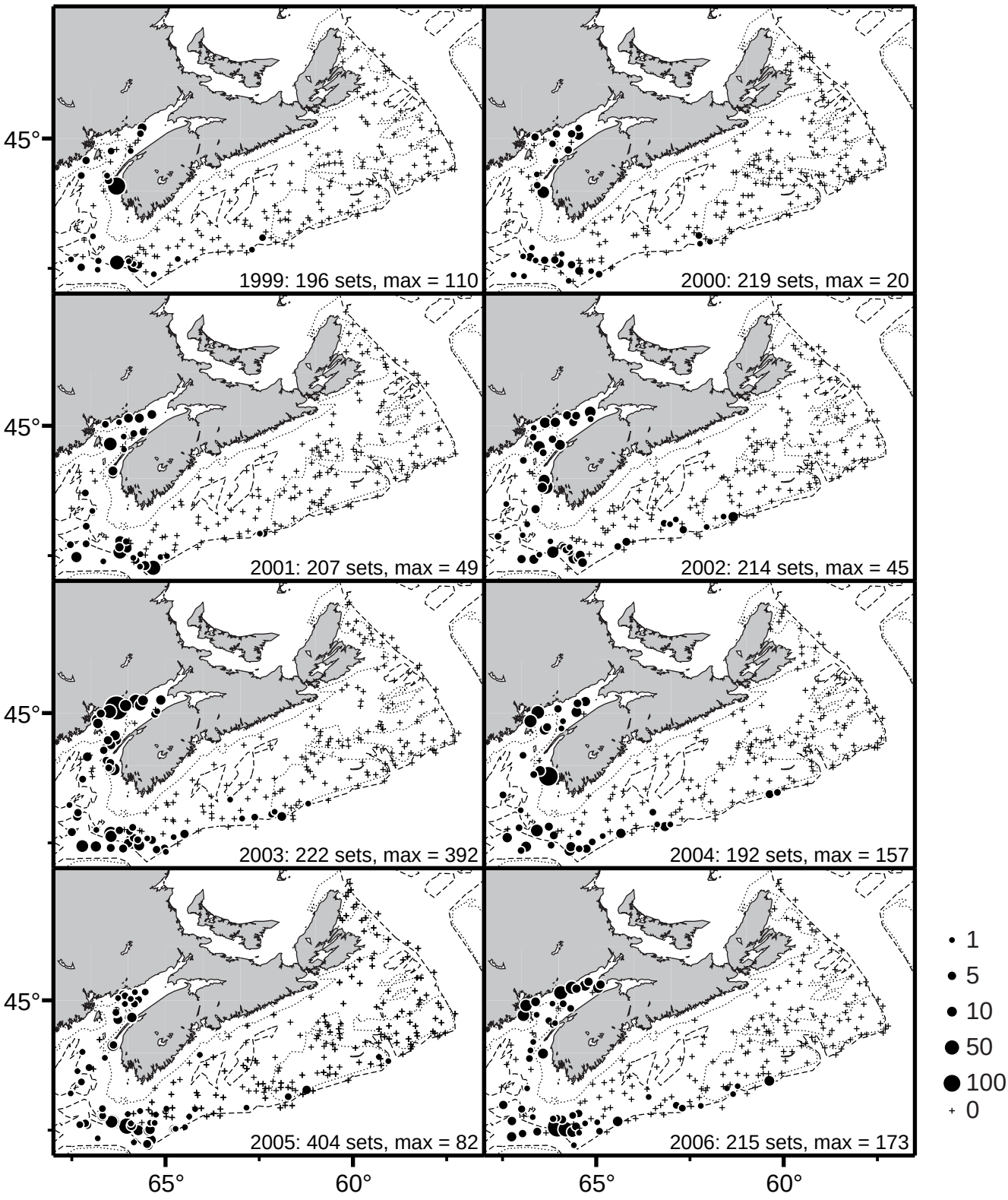

Fig. 5. Number of American Lobsters per tow from the 1999-2006 Summer Ecosystem Surveys.

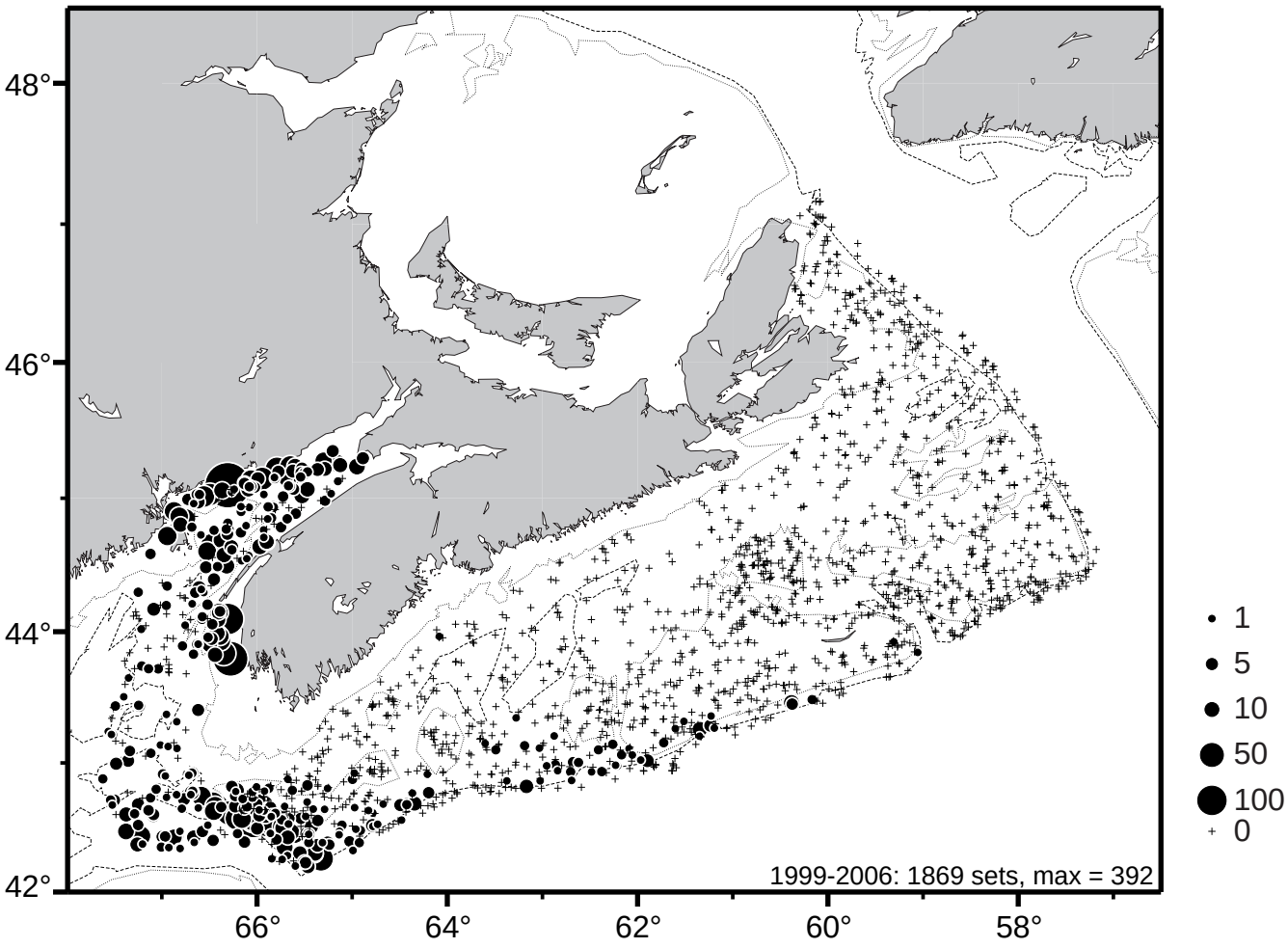

Fig. 6. Number of American Lobsters per tow from the 1999-2006 Summer Ecosystem Surveys.

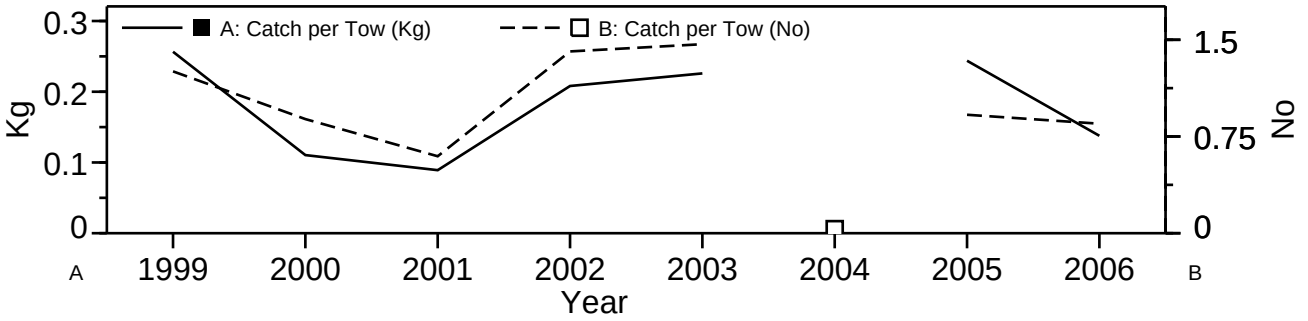

Fig. 7. Jonah crab stratified mean weight caught per tow, stratified mean number caught per tow from the Summer Ecosystem surveys. The catch for 2004 was sampled using the MV Teleost. It has not been calibrated, and should not be compared to the earlier time series.

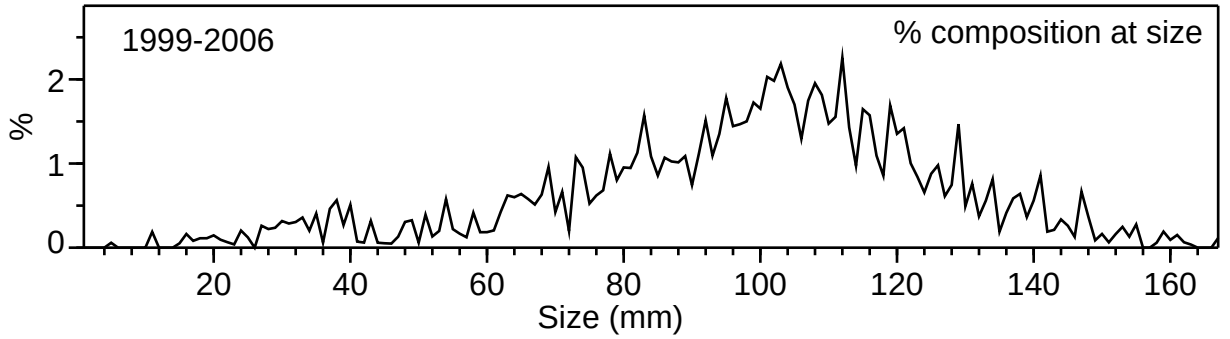

Fig. 8. Jonah crab size frequency distribution from the Summer Ecosystem surveys.

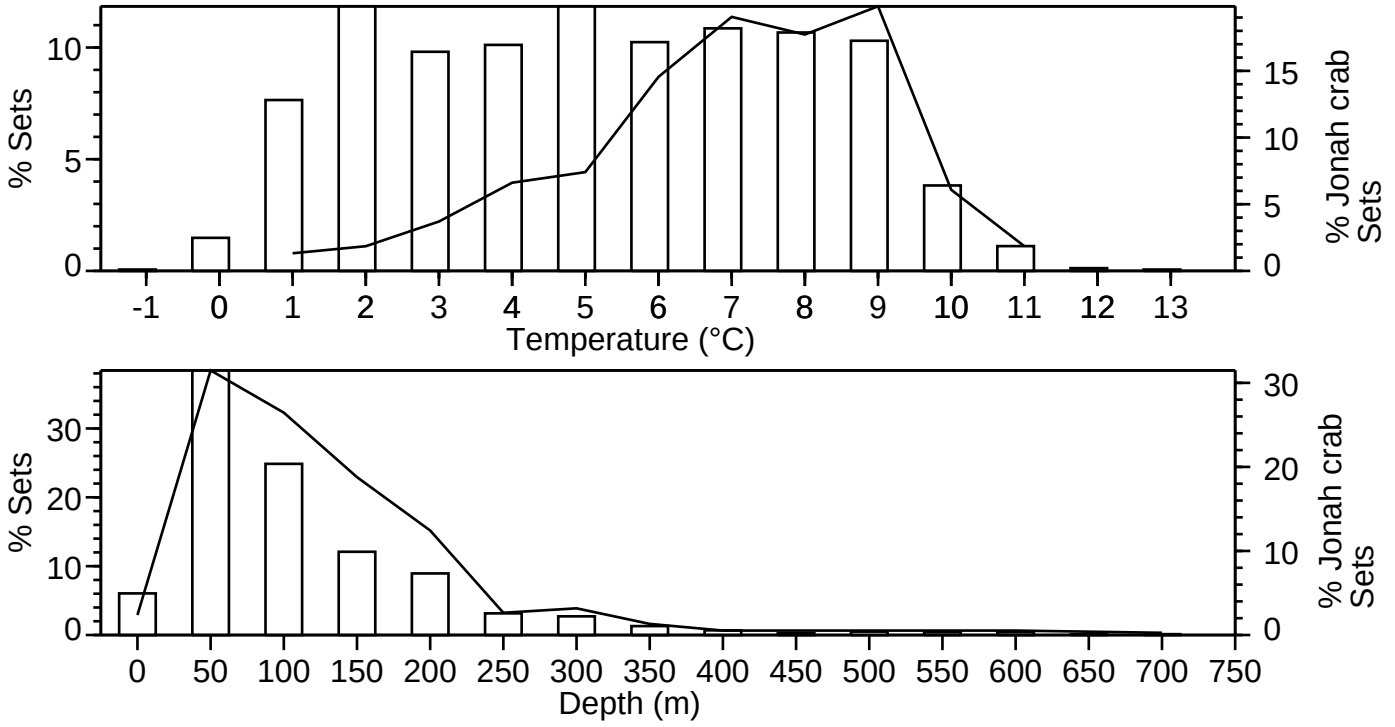

Fig. 9. Temperature and depth distribution of Jonah crab captured from the Summer Ecosystem surveys 1999-2006. Shown for each variable is percentage of sets with Jonah crab within given temperature or depth intervals (line) and percentage of all sets within different temperature or depth intervals (bar graph).

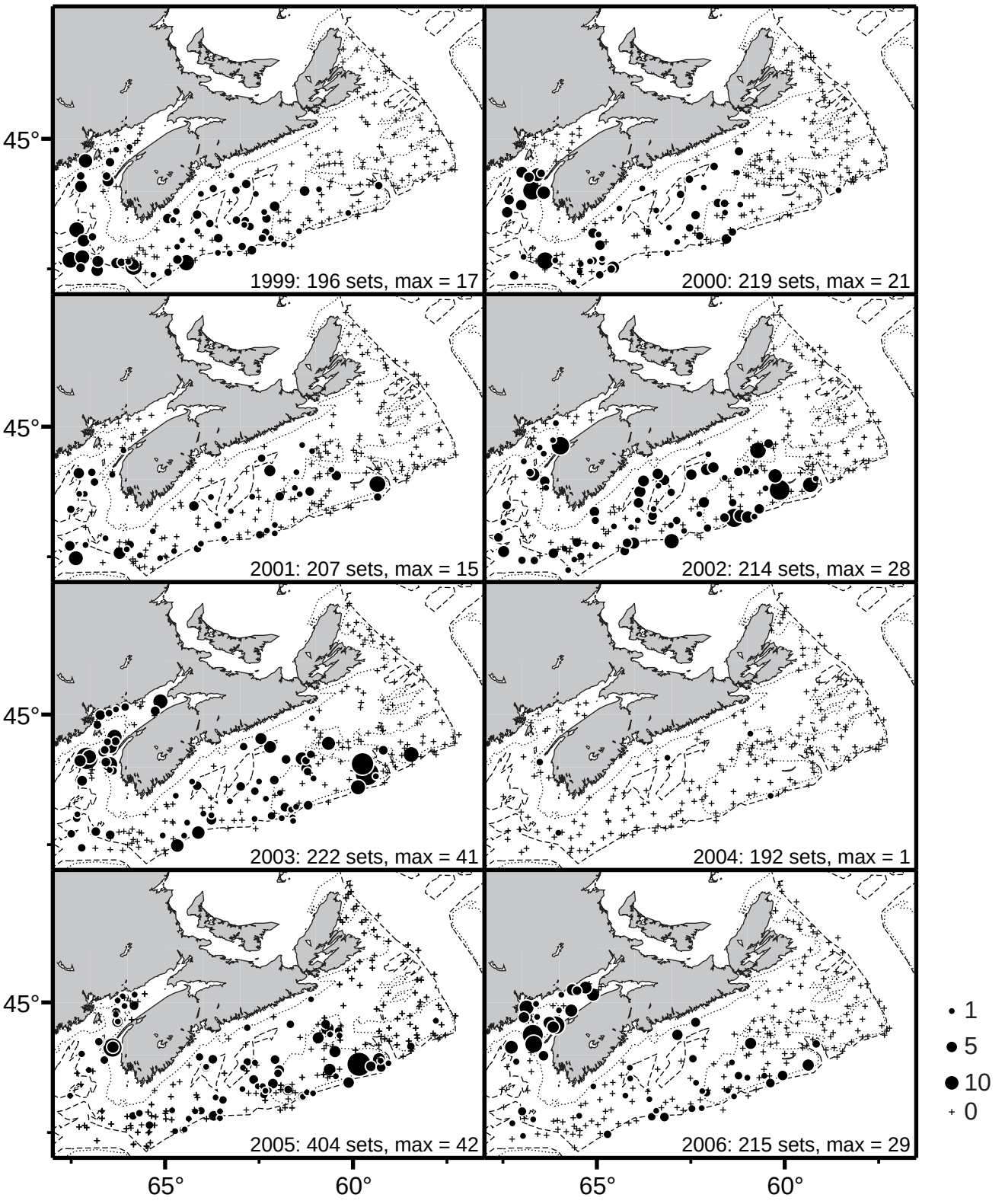

Fig. 10. Number of Jonah crab per tow from the 1999-2006 Summer Ecosystem Surveys.

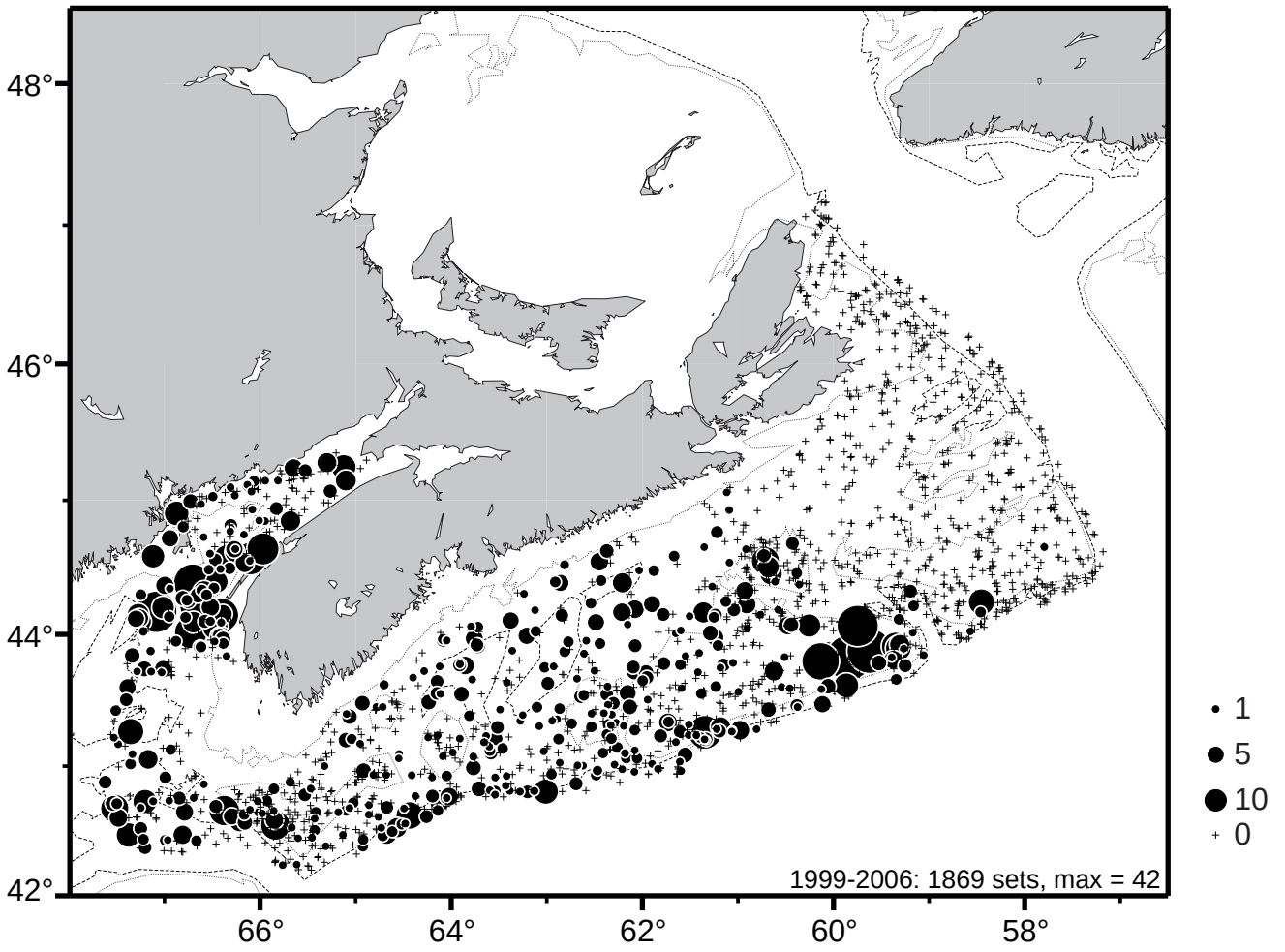

Fig. 11. Number of Jonah crab per tow from the 1999-2006 Summer Ecosystem Surveys.

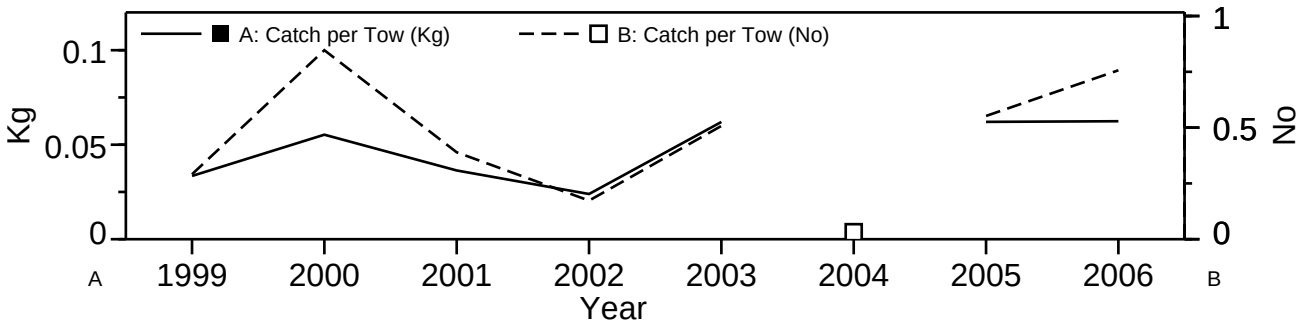

Fig. 12. Rock Crab stratified mean weight caught per tow, stratified mean number caught per tow from the Summer Ecosystem surveys. The catch for 2004 was sampled using the MV Teleost. It has not been calibrated, and should not be compared to the earlier time series.

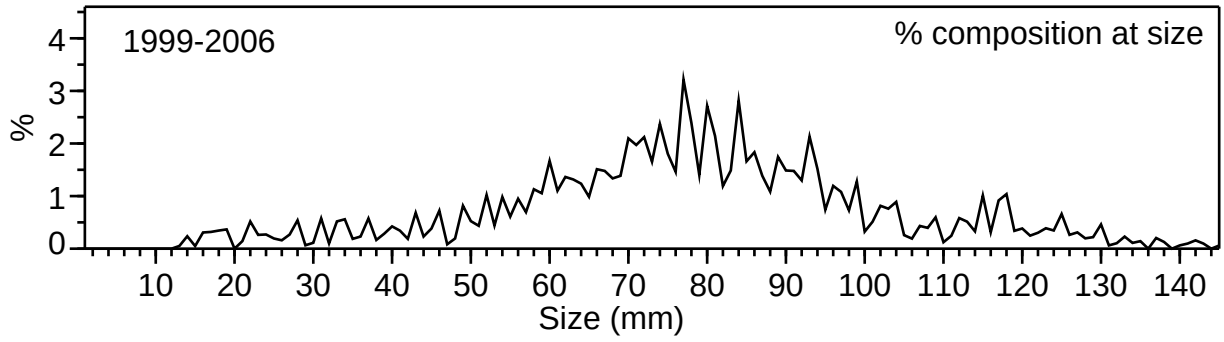

Fig. 13. Rock Crab size frequency distribution from the Summer Ecosystem surveys.

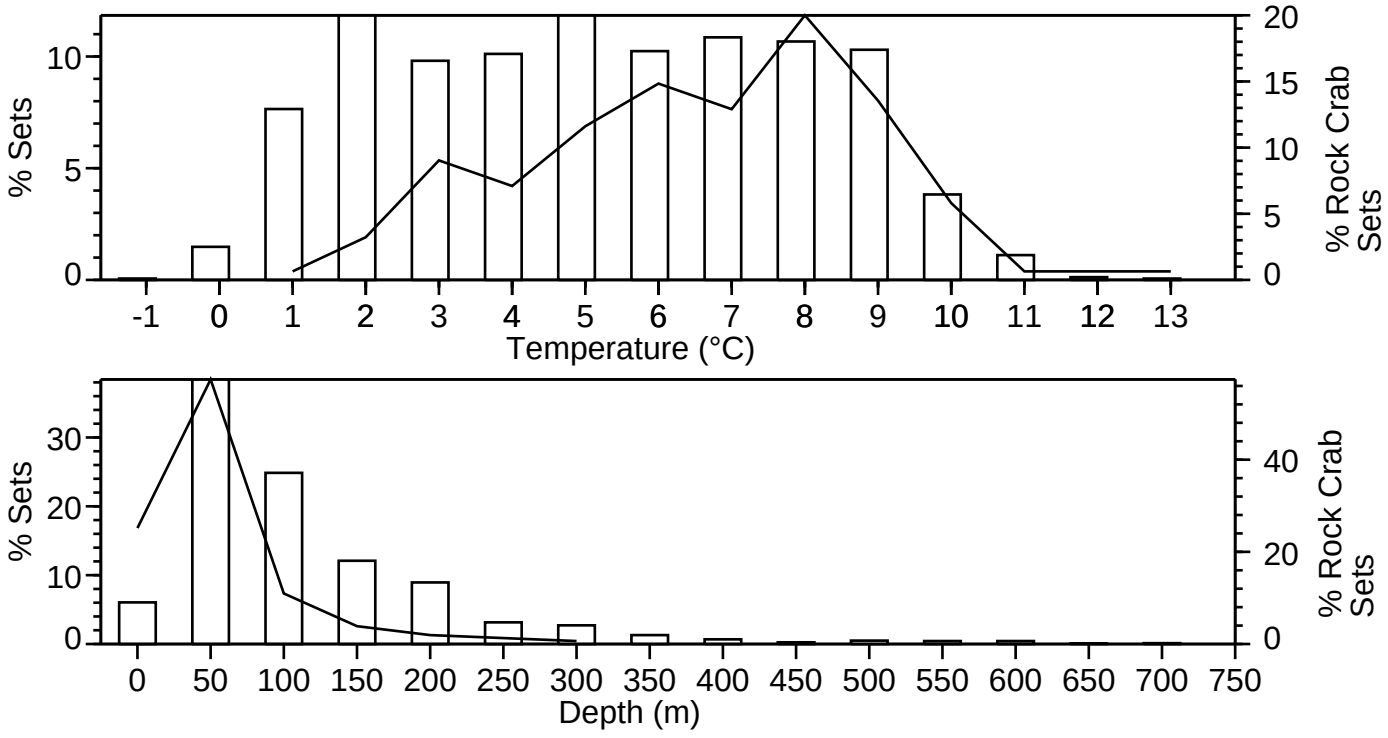

Fig. 14. Temperature and depth distribution of Rock Crab captured from the Summer Ecosystem surveys 1999-2006. Shown for each variable is percentage of sets with Rock Crab within given temperature or depth intervals (line) and percentage of all sets within different temperature or depth intervals (bar graph).

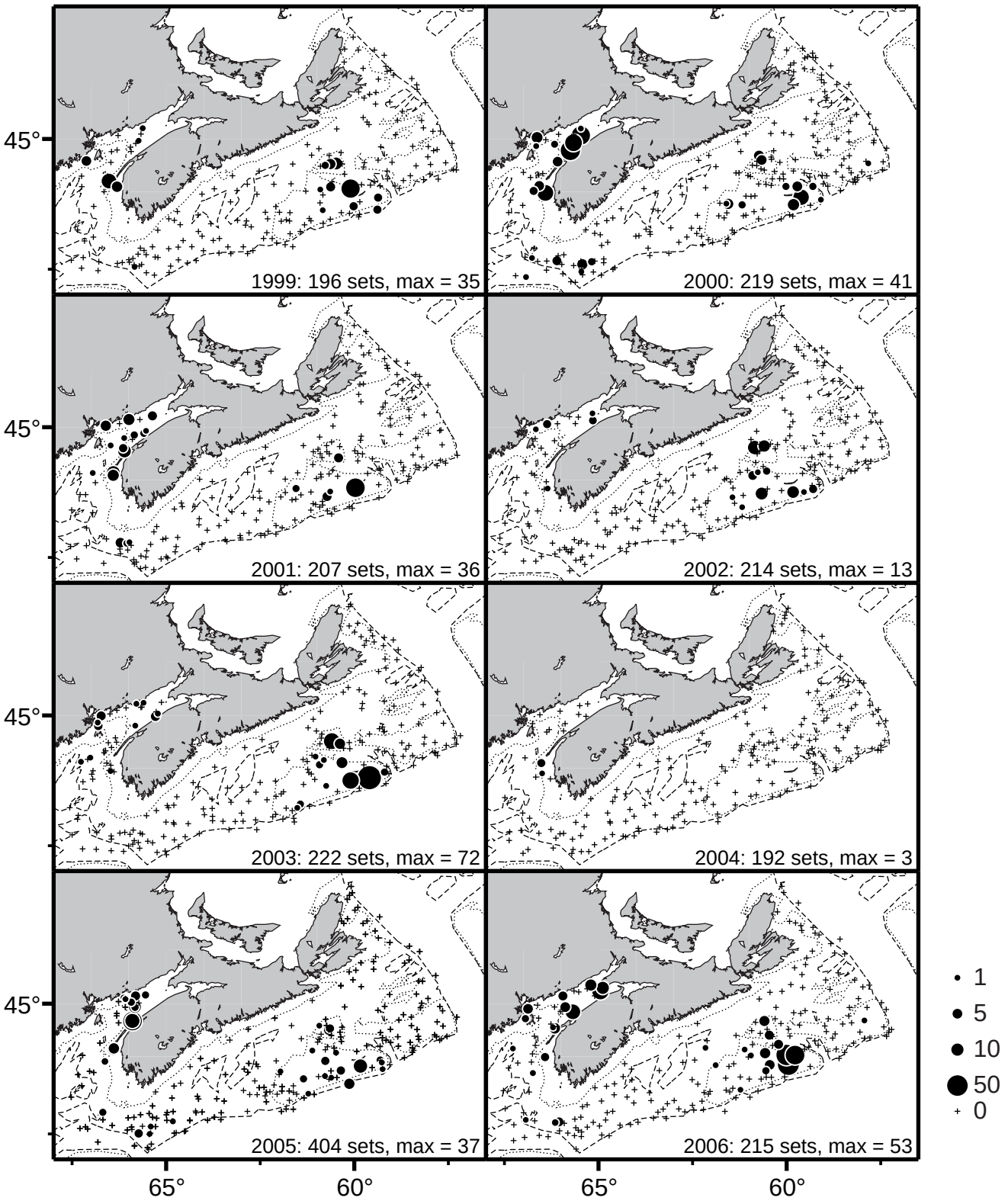

Fig. 15. Number of Rock Crab per tow from the 1999-2006 Summer Ecosystem Surveys.

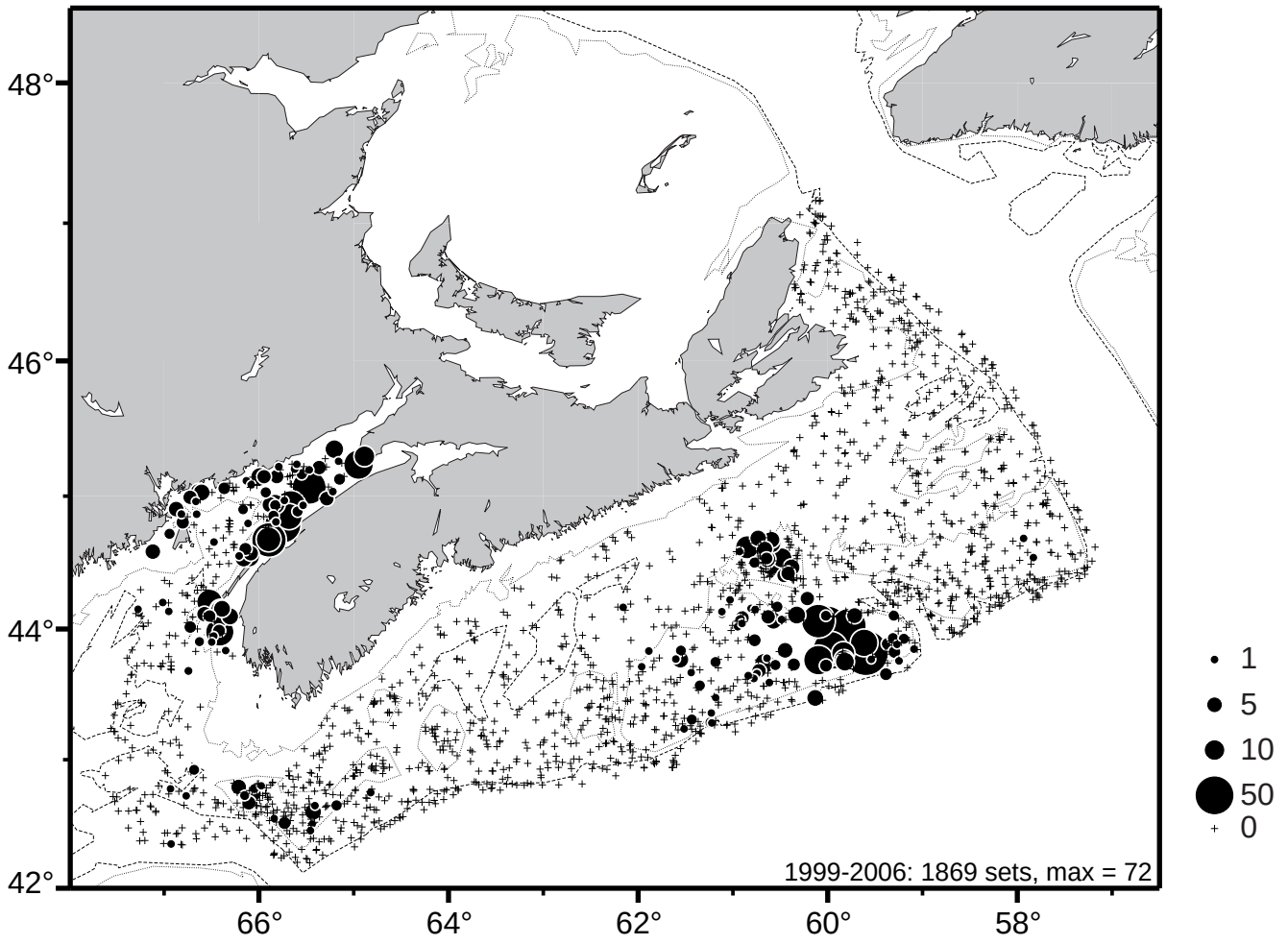

Fig. 16. Number of Rock Crab per tow from the 1999-2006 Summer Ecosystem Surveys.

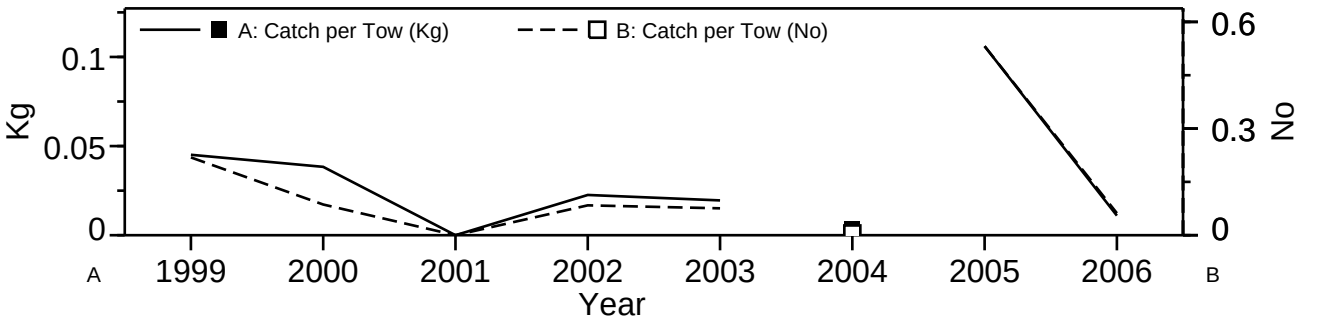

Fig. 17. Red Crab stratified mean weight caught per tow, stratified mean number caught per tow from the Summer Ecosystem surveys. The catch for 2004 was sampled using the MV Teleost. It has not been calibrated, and should not be compared to the earlier time series.

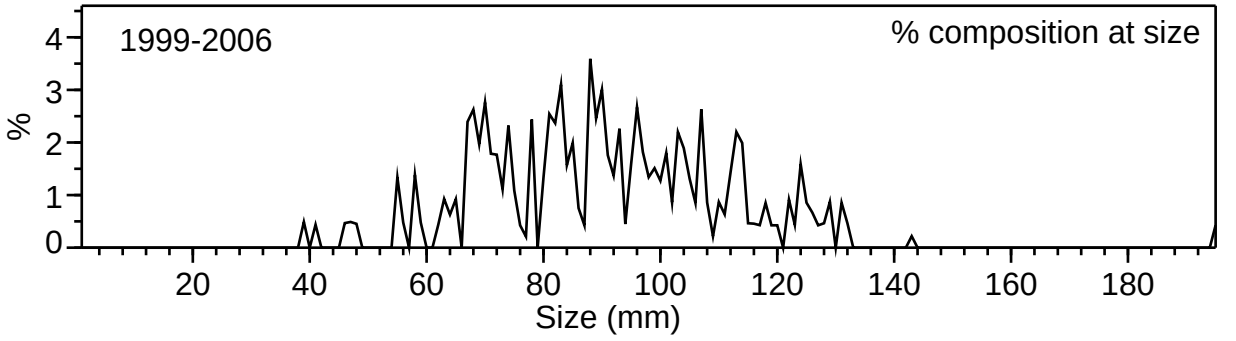

Fig. 18. Red Crab size frequency distribution from the Summer Ecosystem surveys.

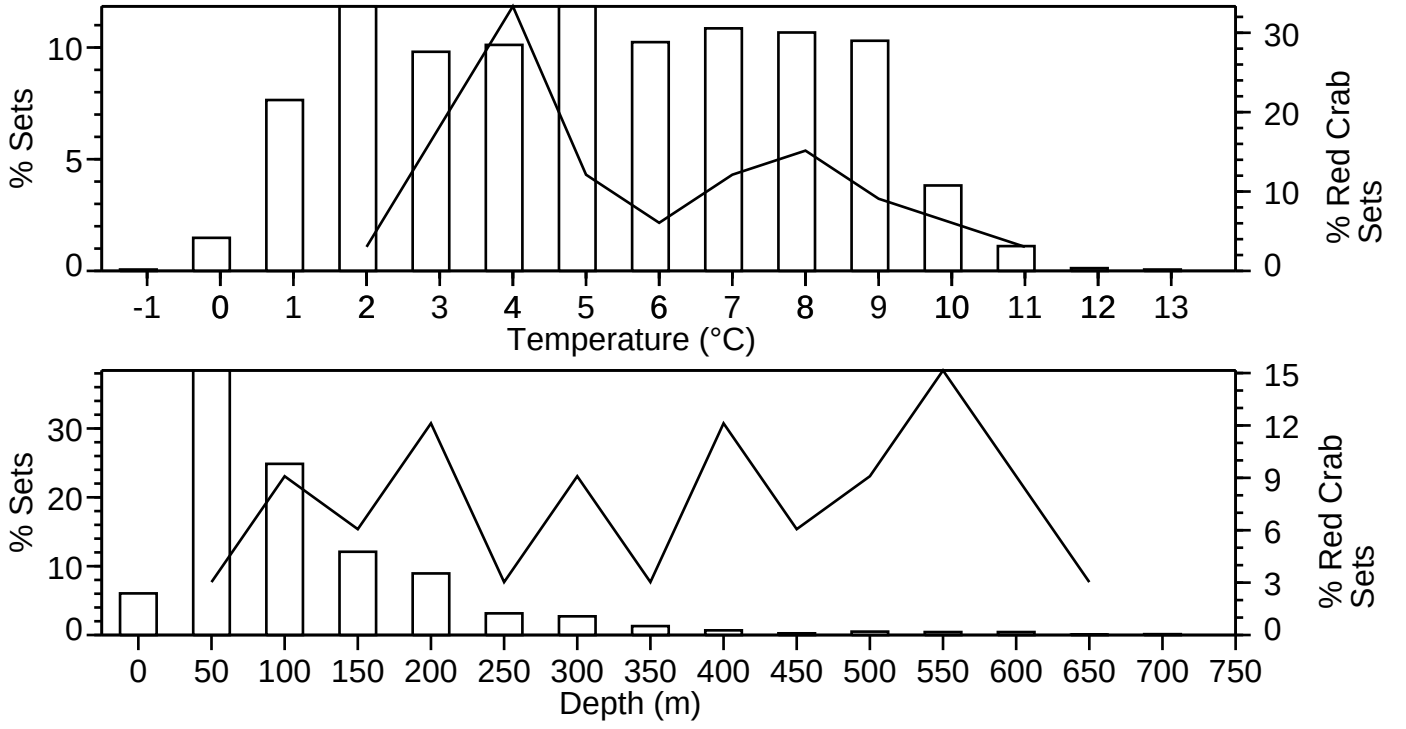

Fig. 19. Temperature and depth distribution of Red Crab captured from the Summer Ecosystem surveys 1999-2006. Shown for each variable is percentage of sets with Red Crab within given temperature or depth intervals (line) and percentage of all sets within different temperature or depth intervals (bar graph).

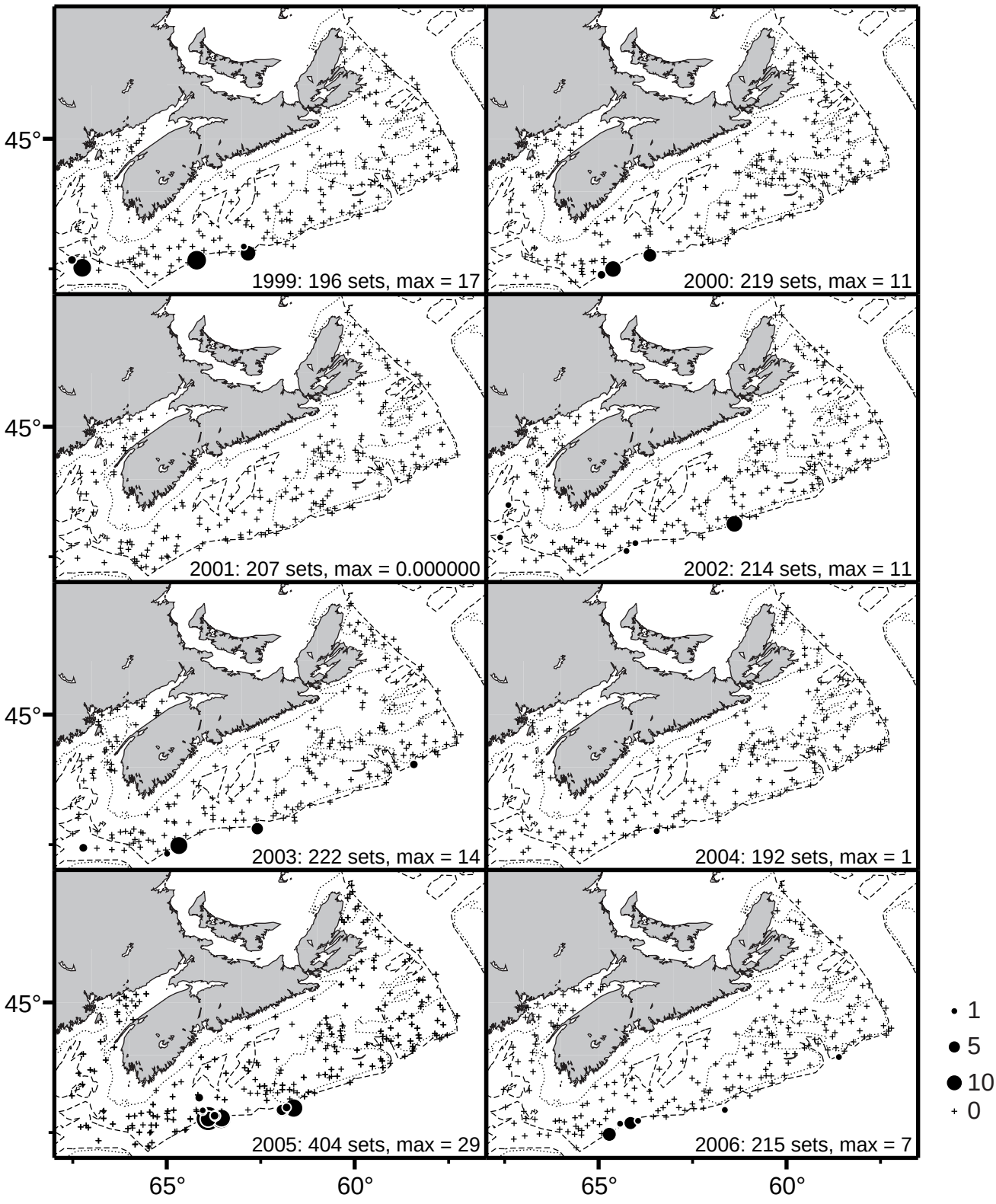

Fig. 20. Number of Red Crab per tow from the 1999-2006 Summer Ecosystem Surveys.

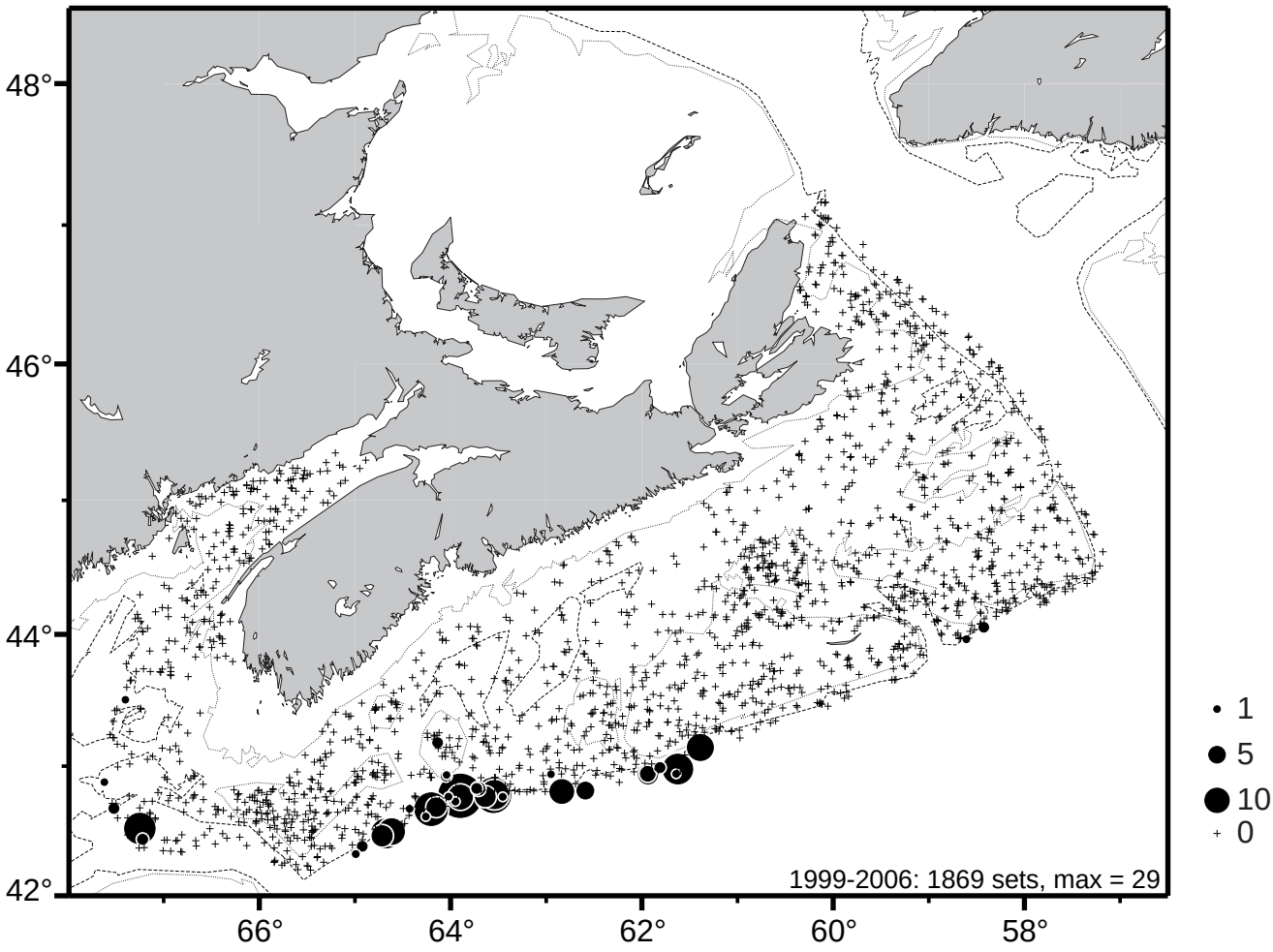

Fig. 21. Number of Red Crab per tow from the 1999-2006 Summer Ecosystem Surveys.

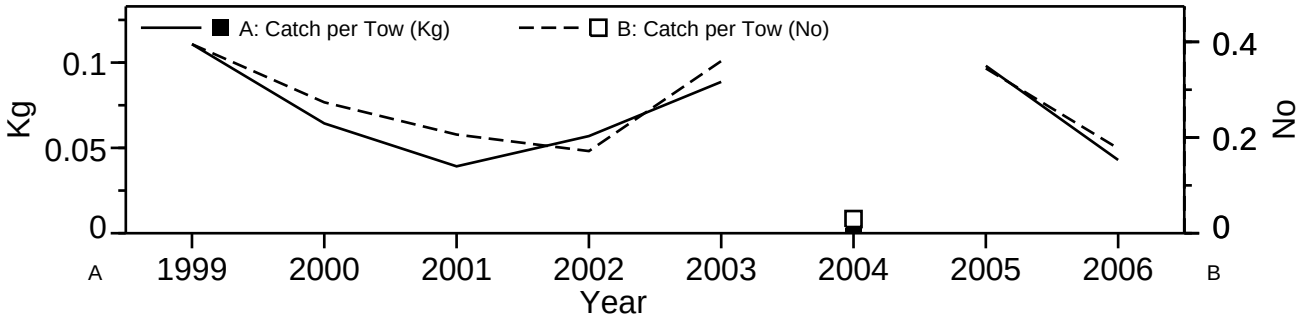

Fig. 22. Northern Stone Crab stratified mean weight caught per tow, stratified mean number caught per tow from the Summer Ecosystem surveys. The catch for 2004 was sampled using the MV Teleost. It has not been calibrated, and should not be compared to the earlier time series.

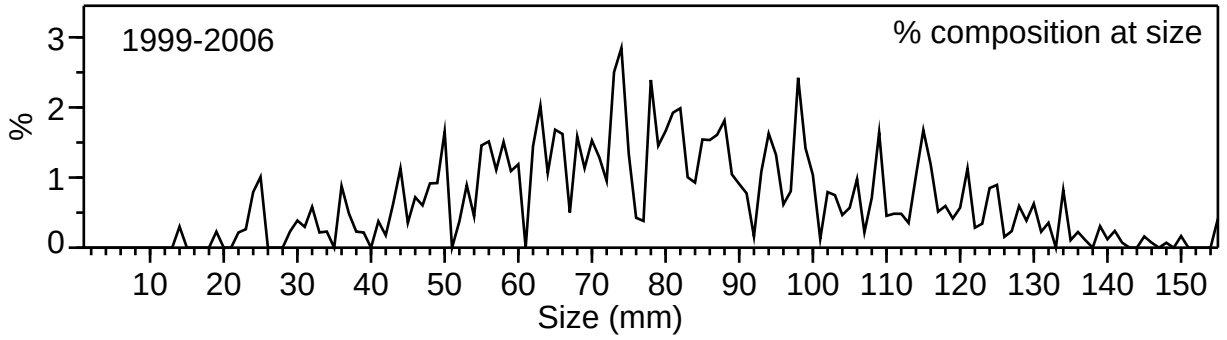

Fig. 23. Northern Stone Crab size frequency distribution from the Summer Ecosystem surveys.

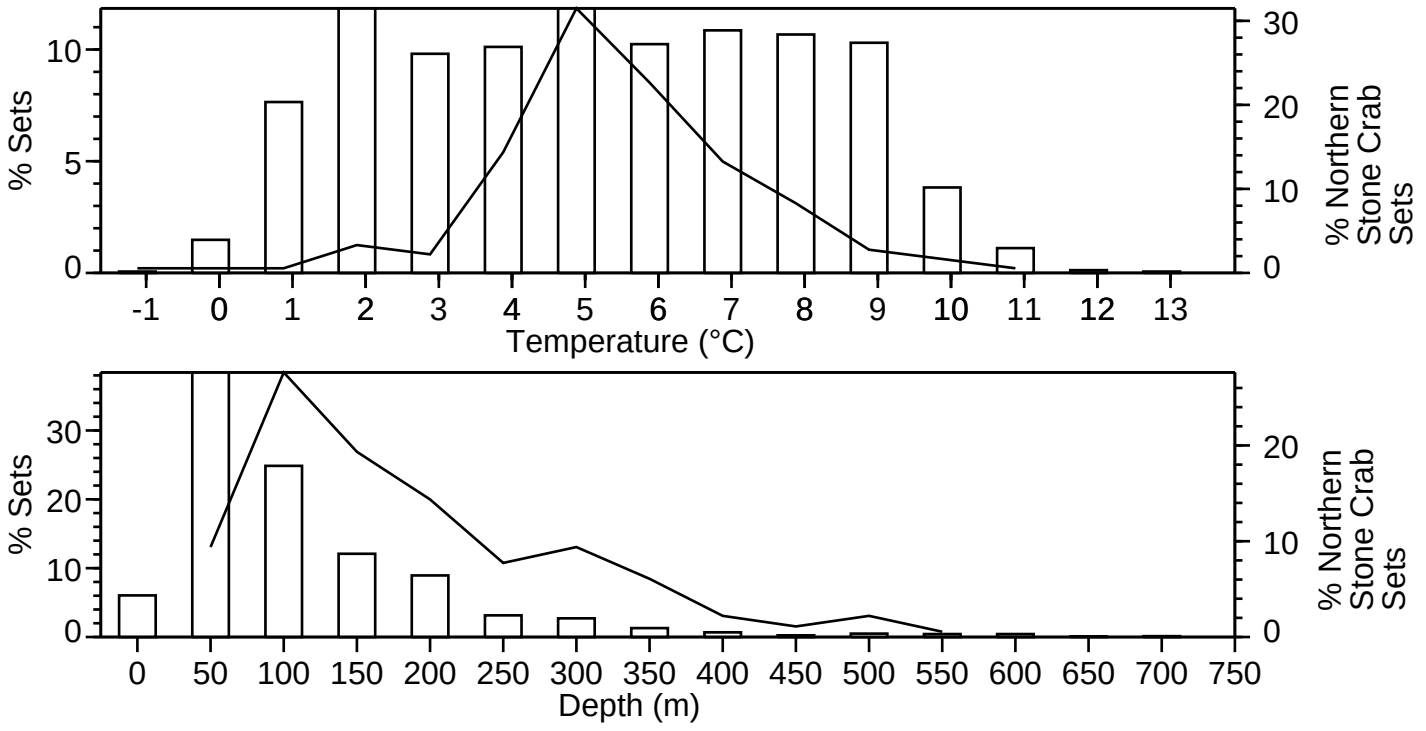

Fig. 24. Temperature and depth distribution of Northern Stone Crab captured from the Summer Ecosystem surveys 1999-2006. Shown for each variable is percentage of sets with Northern Stone Crab within given temperature or depth intervals (line) and percentage of all sets within different temperature or depth intervals (bar graph).

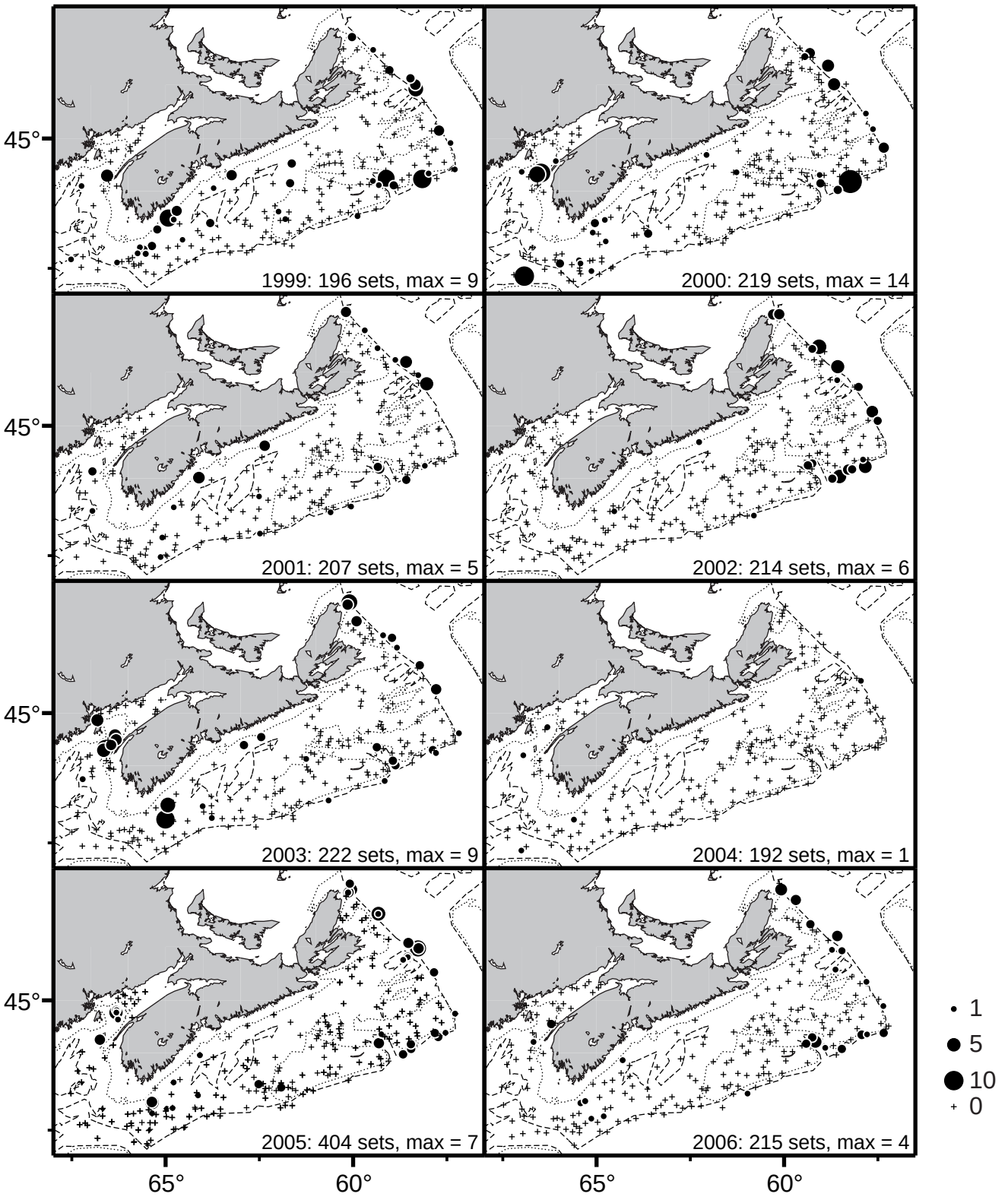

Fig. 25. Number of Northern Stone Crab per tow from the 1999-2006 Summer Ecosystem Surveys.

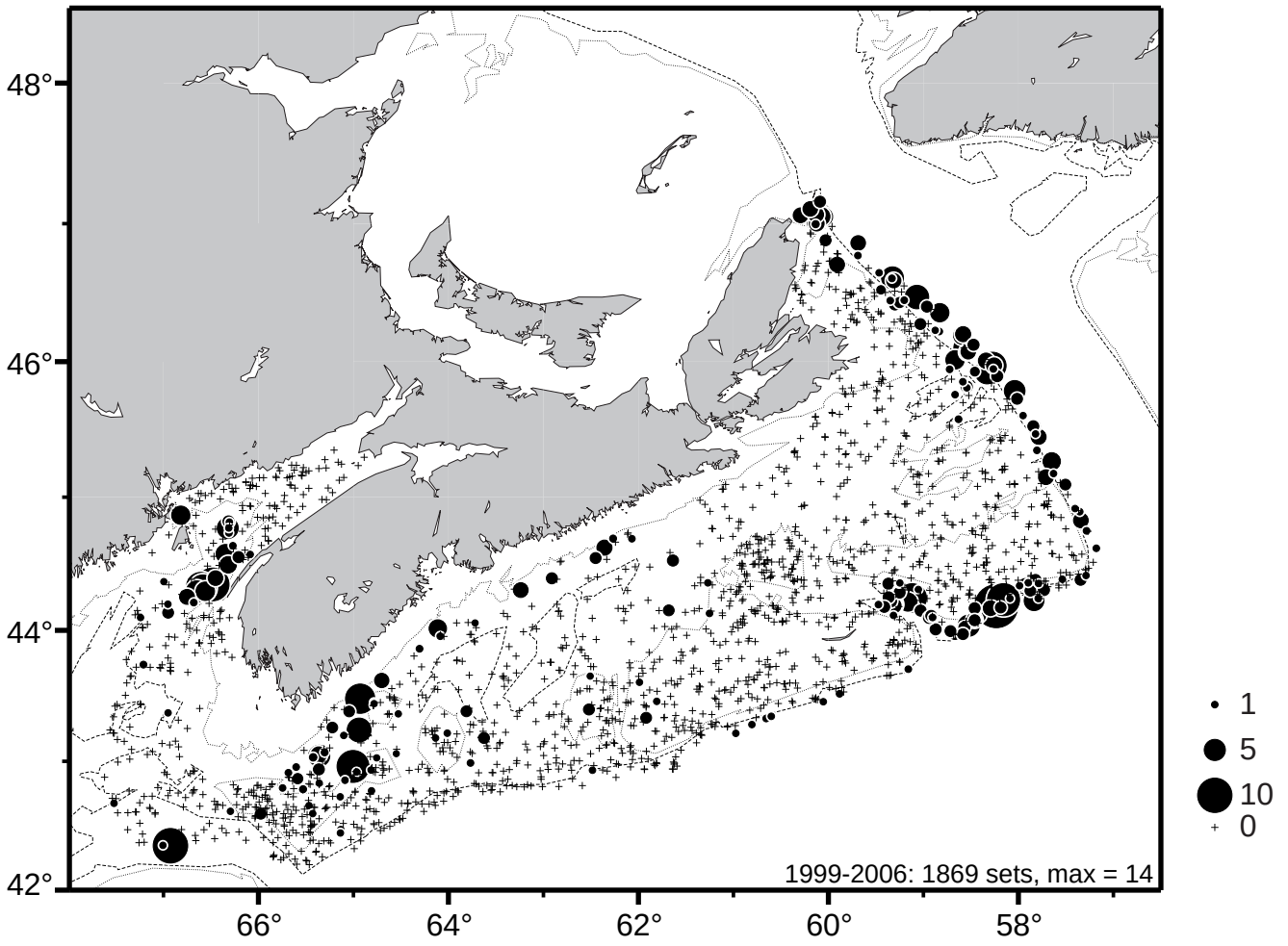

Fig. 26. Number of Northern Stone Crab per tow from the 1999-2006 Summer Ecosystem Surveys.

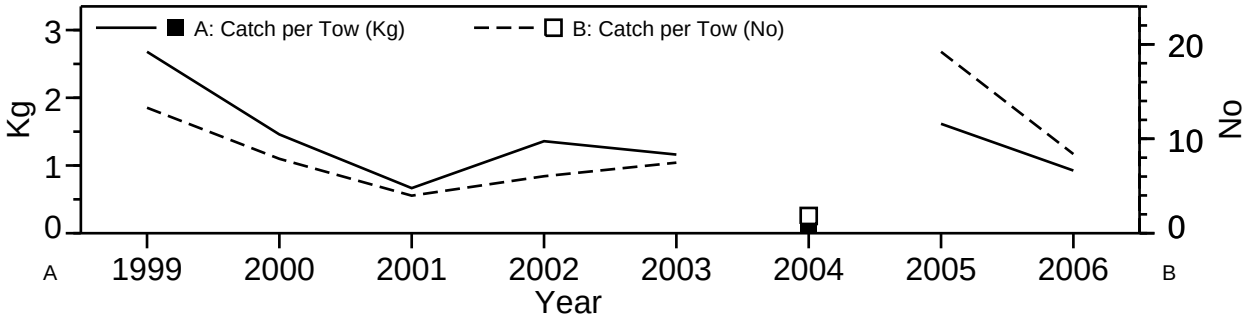

Fig. 27. Snow Crab stratified mean weight caught per tow, stratified mean number caught per tow from the Summer Ecosystem surveys. The catch for 2004 was sampled using the MV Teleost. It has not been calibrated, and should not be compared to the earlier time series.

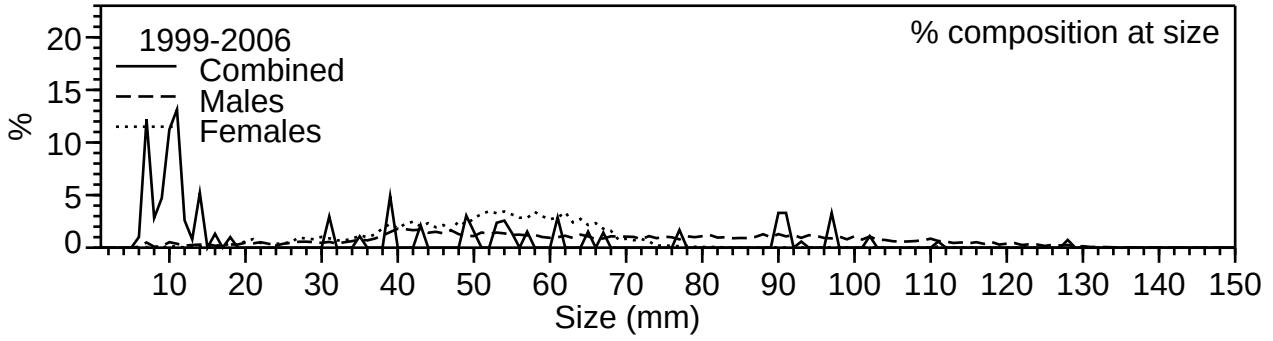

Fig. 28. Snow Crab size frequency distribution from the Summer Ecosystem surveys.

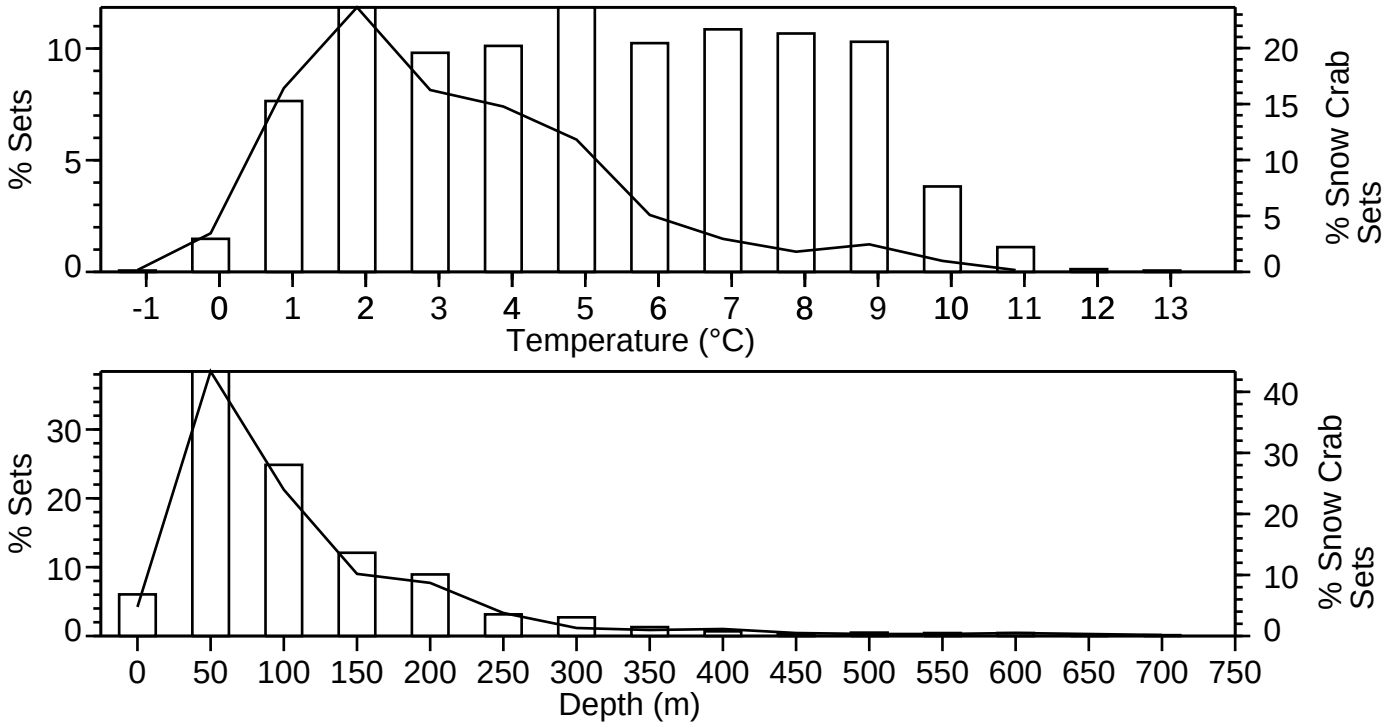

Fig. 29. Temperature and depth distribution of Snow Crab captured from the Summer Ecosystem surveys 1999-2006. Shown for each variable is percentage of sets with Snow Crab within given temperature or depth intervals (line) and percentage of all sets within different temperature or depth intervals (bar graph).

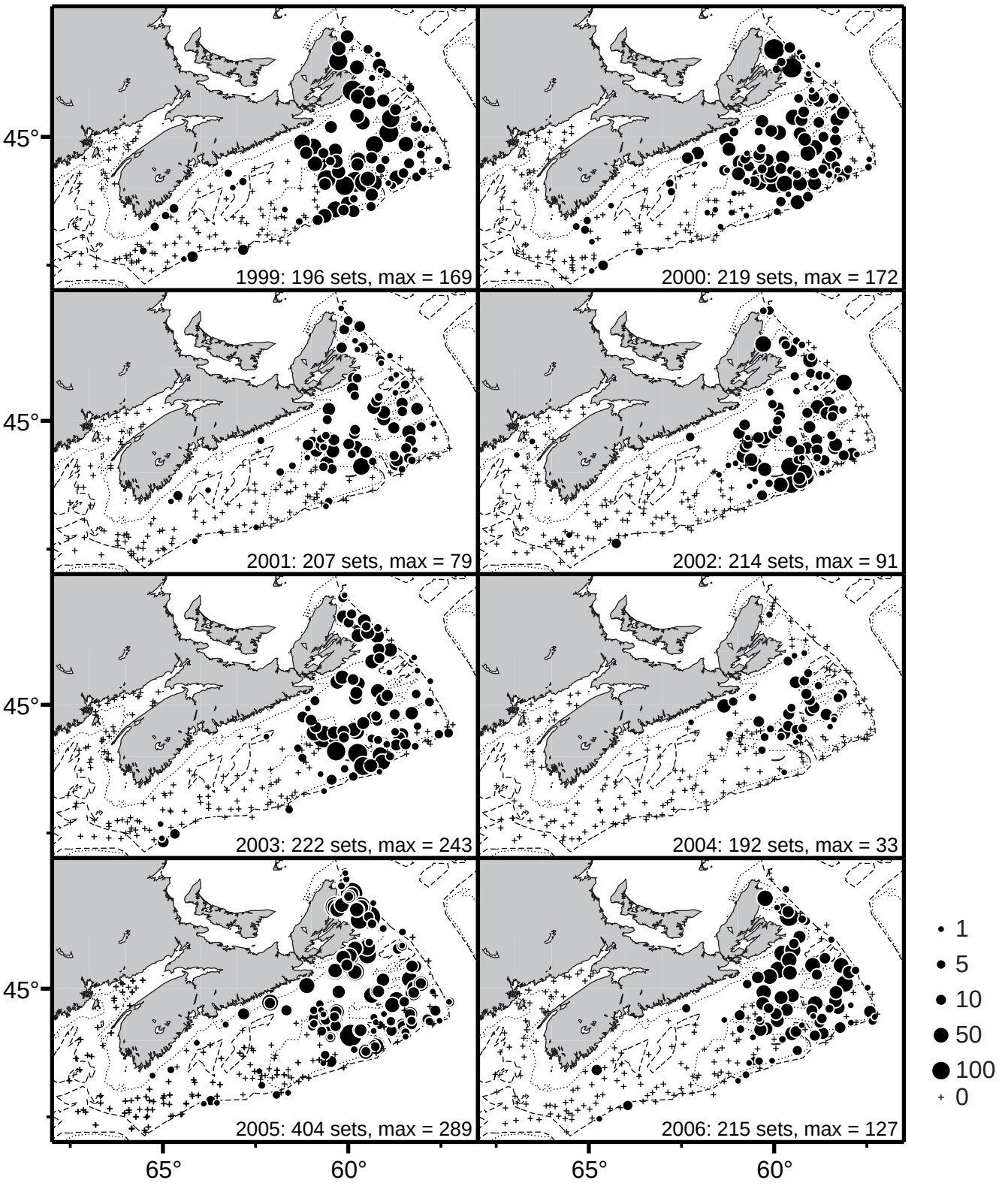

Fig. 30. Number of Snow Crab per tow from the 1999-2006 Summer Ecosystem Surveys.

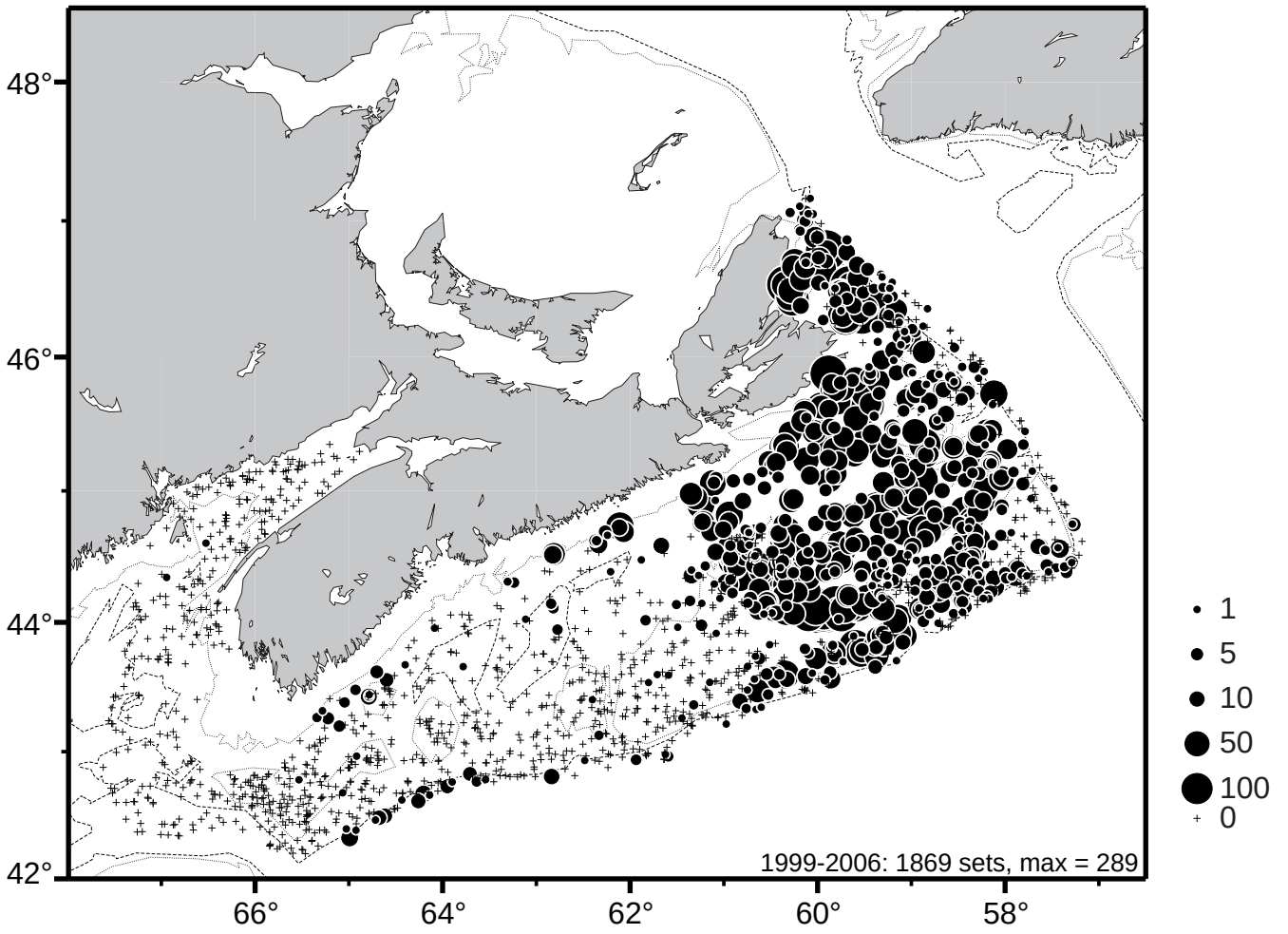

Fig. 31. Number of Snow Crab per tow from the 1999-2006 Summer Ecosystem Surveys.

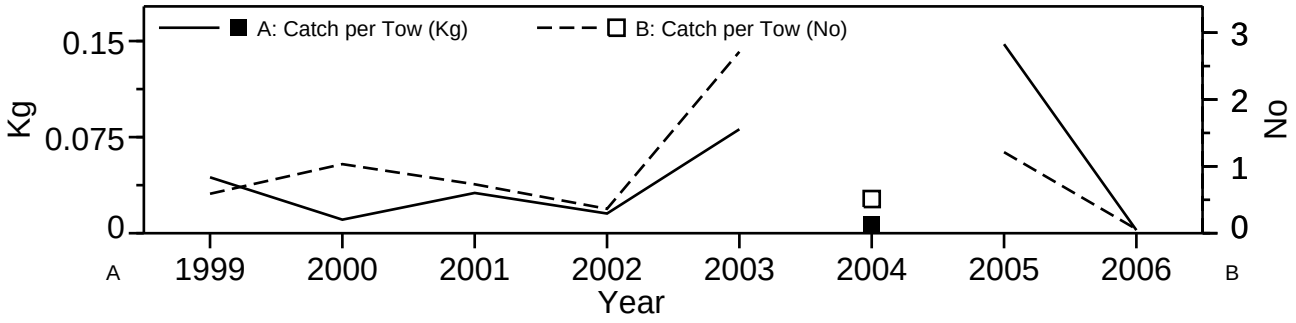

Fig. 32. Toad Crab stratified mean weight caught per tow, stratified mean number caught per tow from the Summer Ecosystem surveys. The catch for 2004 was sampled using the MV Teleost. It has not been calibrated, and should not be compared to the earlier time series.

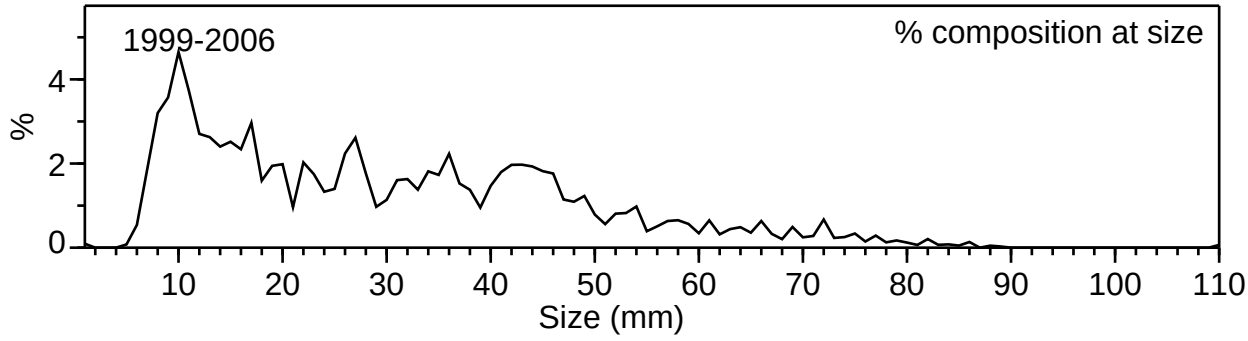

Fig. 33. Toad Crab size frequency distribution from the Summer Ecosystem surveys.

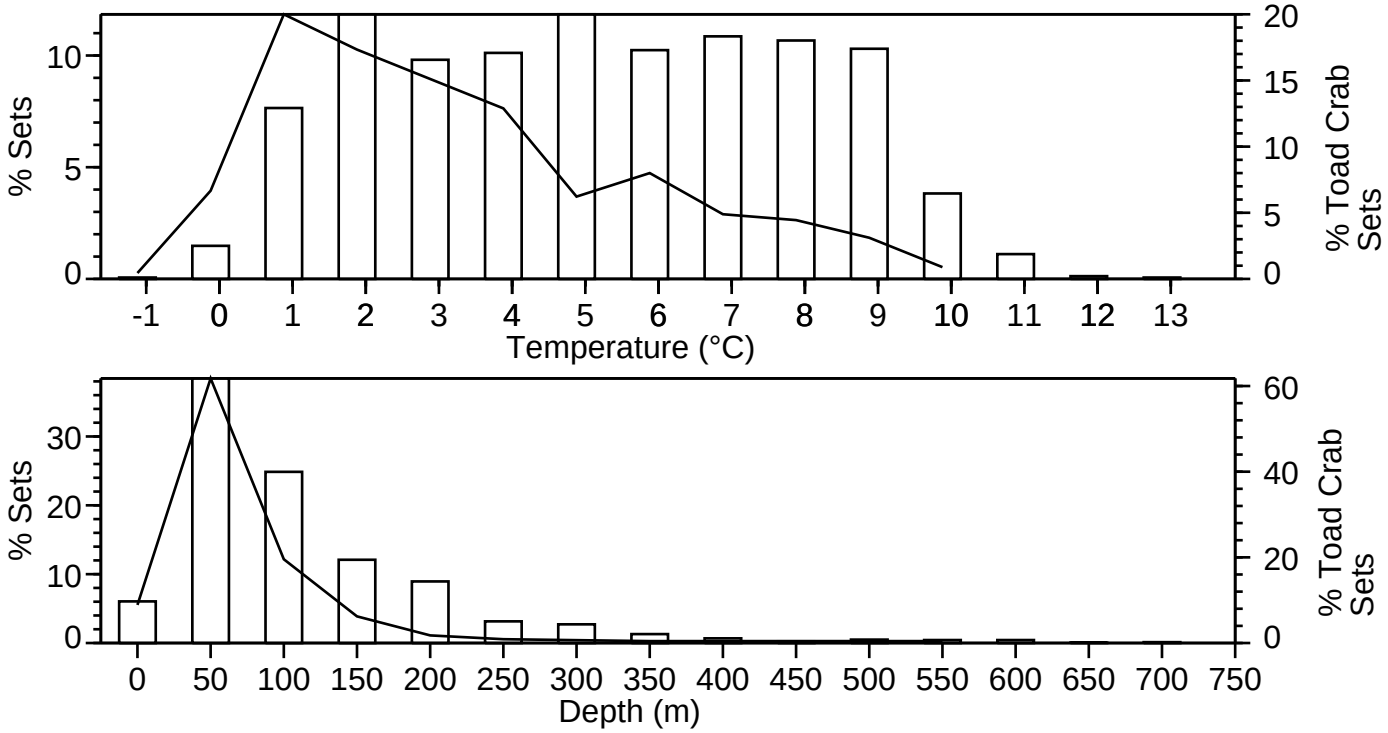

Fig. 34. Temperature and depth distribution of Toad Crab captured from the Summer Ecosystem surveys 1999-2006. Shown for each variable is percentage of sets with Toad Crab within given temperature or depth intervals (line) and percentage of all sets within different temperature or depth intervals (bar graph).

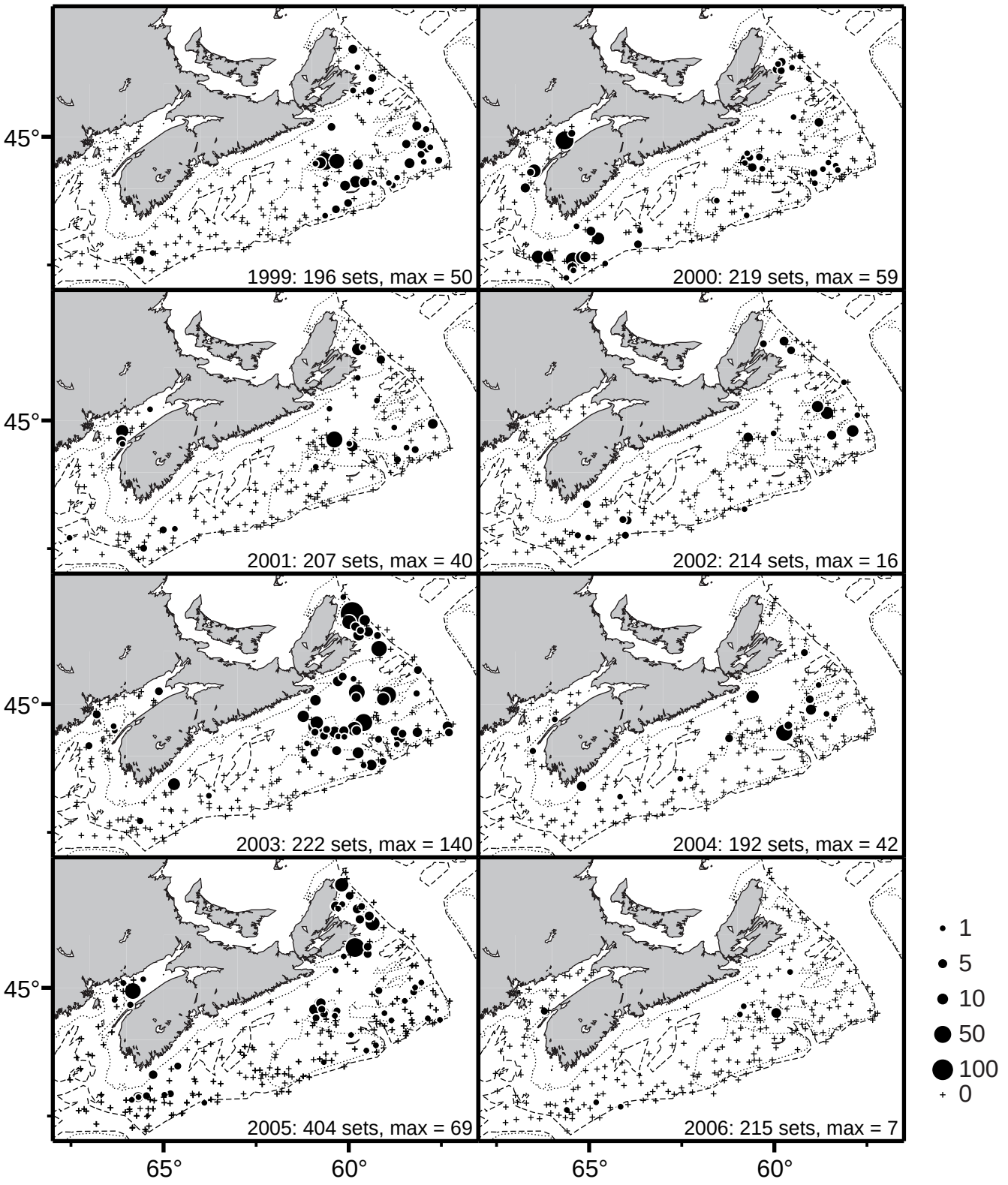

Fig. 35. Number of Toad Crab per tow from the 1999-2006 Summer Ecosystem Surveys.

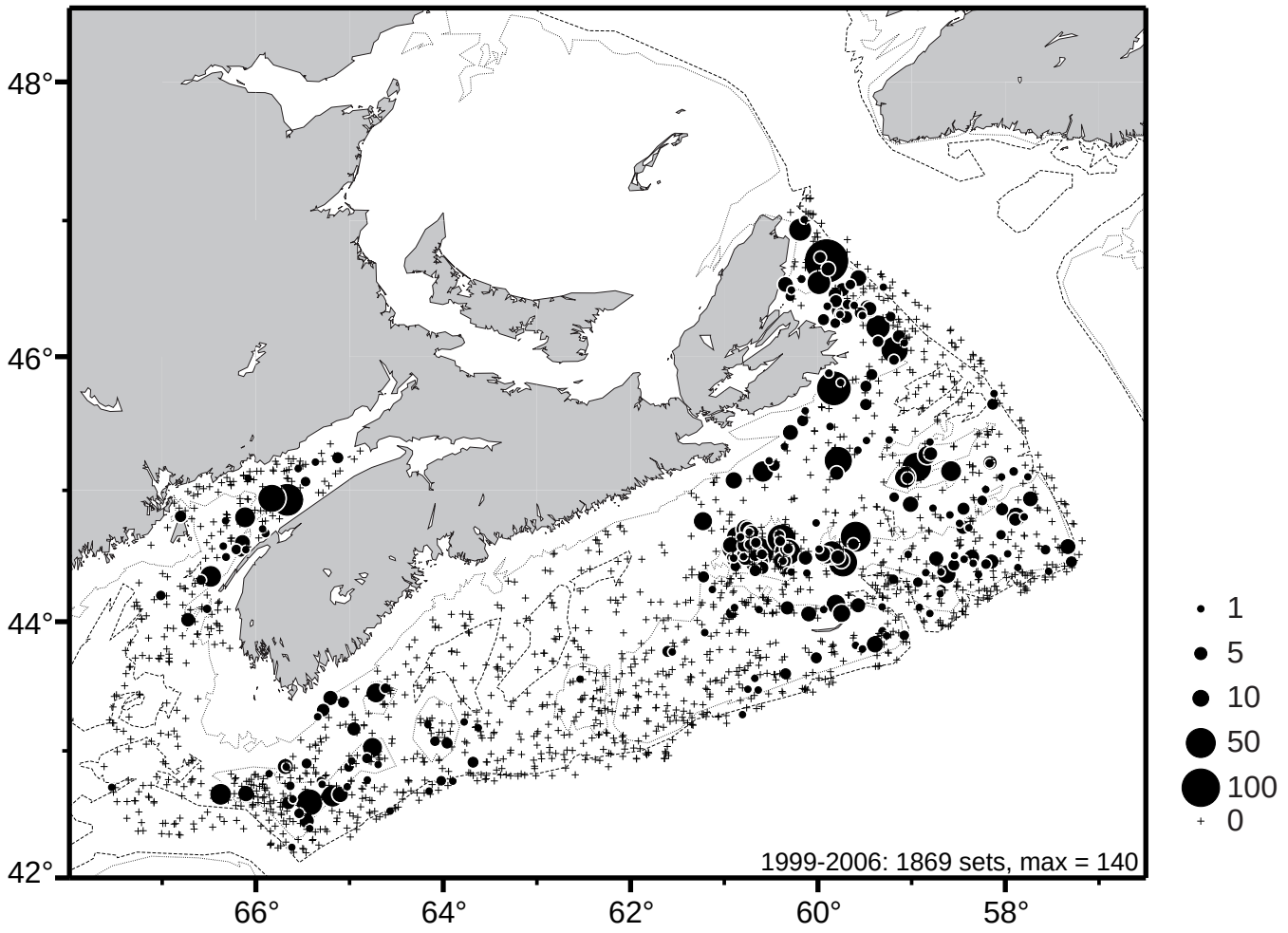

Fig. 36. Number of Toad Crab per tow from the 1999-2006 Summer Ecosystem Surveys.

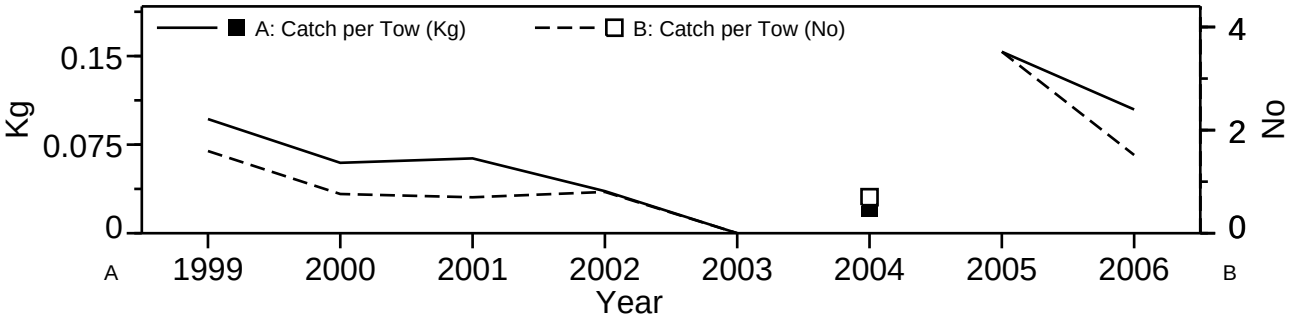

Fig. 37. Lyre Crab stratified mean weight caught per tow, stratified mean number caught per tow from the Summer Ecosystem surveys. The catch for 2004 was sampled using the MV Teleost. It has not been calibrated, and should not be compared to the earlier time series.

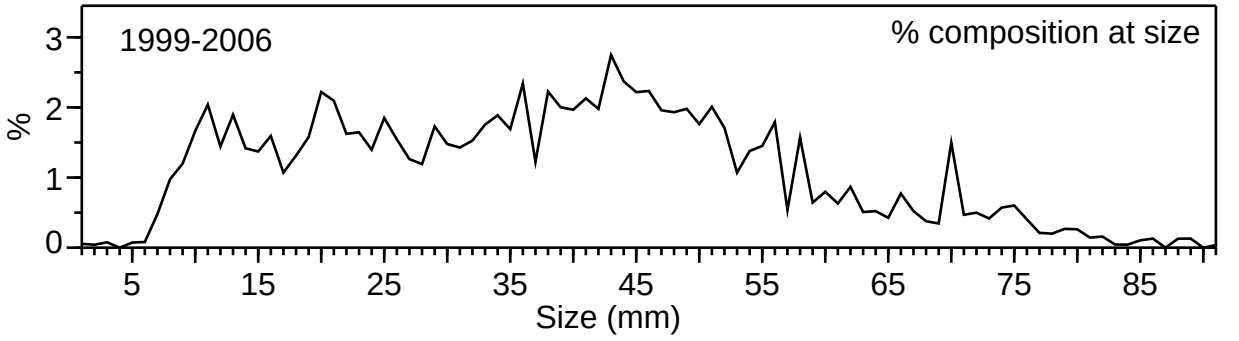

Fig. 38. Lyre Crab size frequency distribution from the Summer Ecosystem surveys.

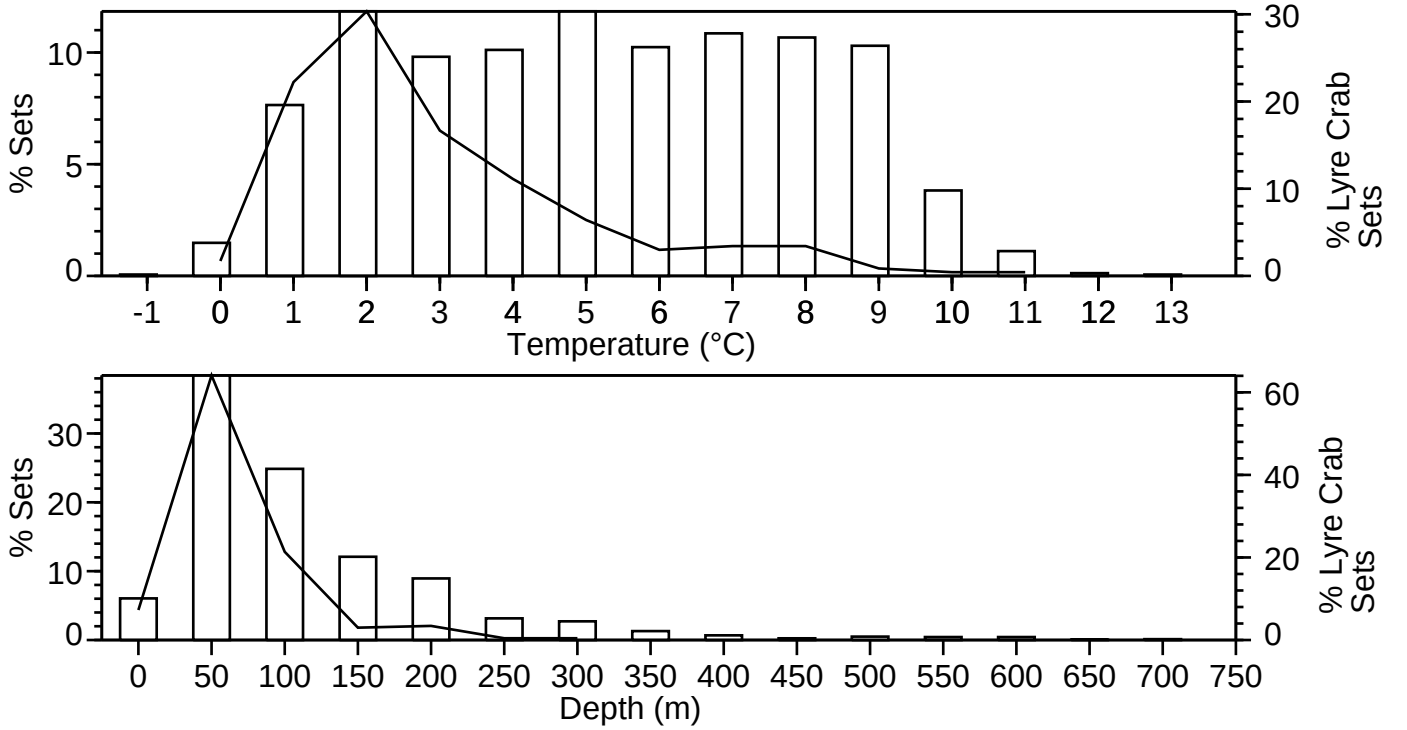

Fig. 39. Temperature and depth distribution of Lyre Crab captured from the Summer Ecosystem surveys 1999-2006. Shown for each variable is percentage of sets with Lyre Crab within given temperature or depth intervals (line) and percentage of all sets within different temperature or depth intervals (bar graph).

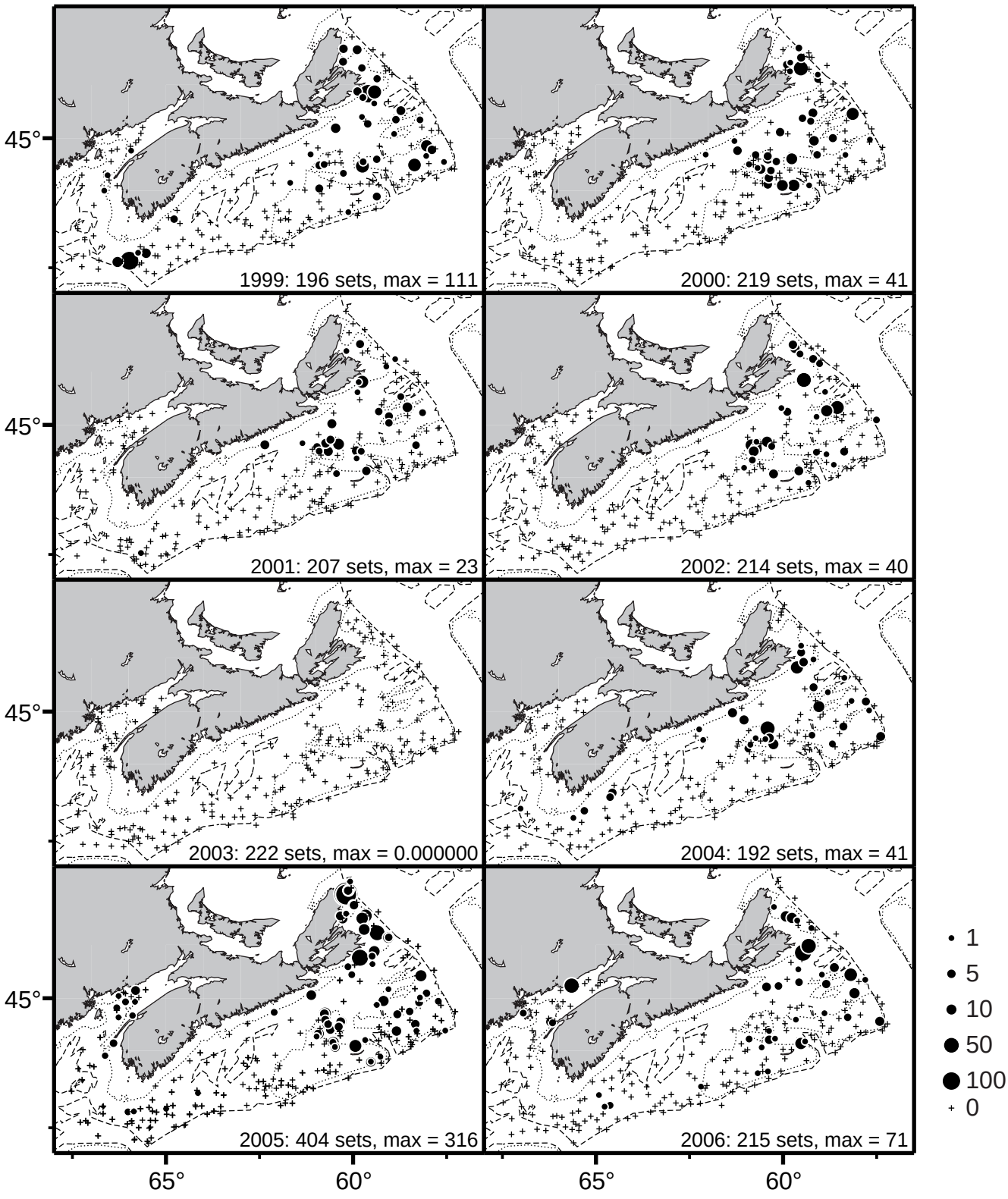

Fig. 40. Number of Lyre Crab per tow from the 1999-2006 Summer Ecosystem Surveys.

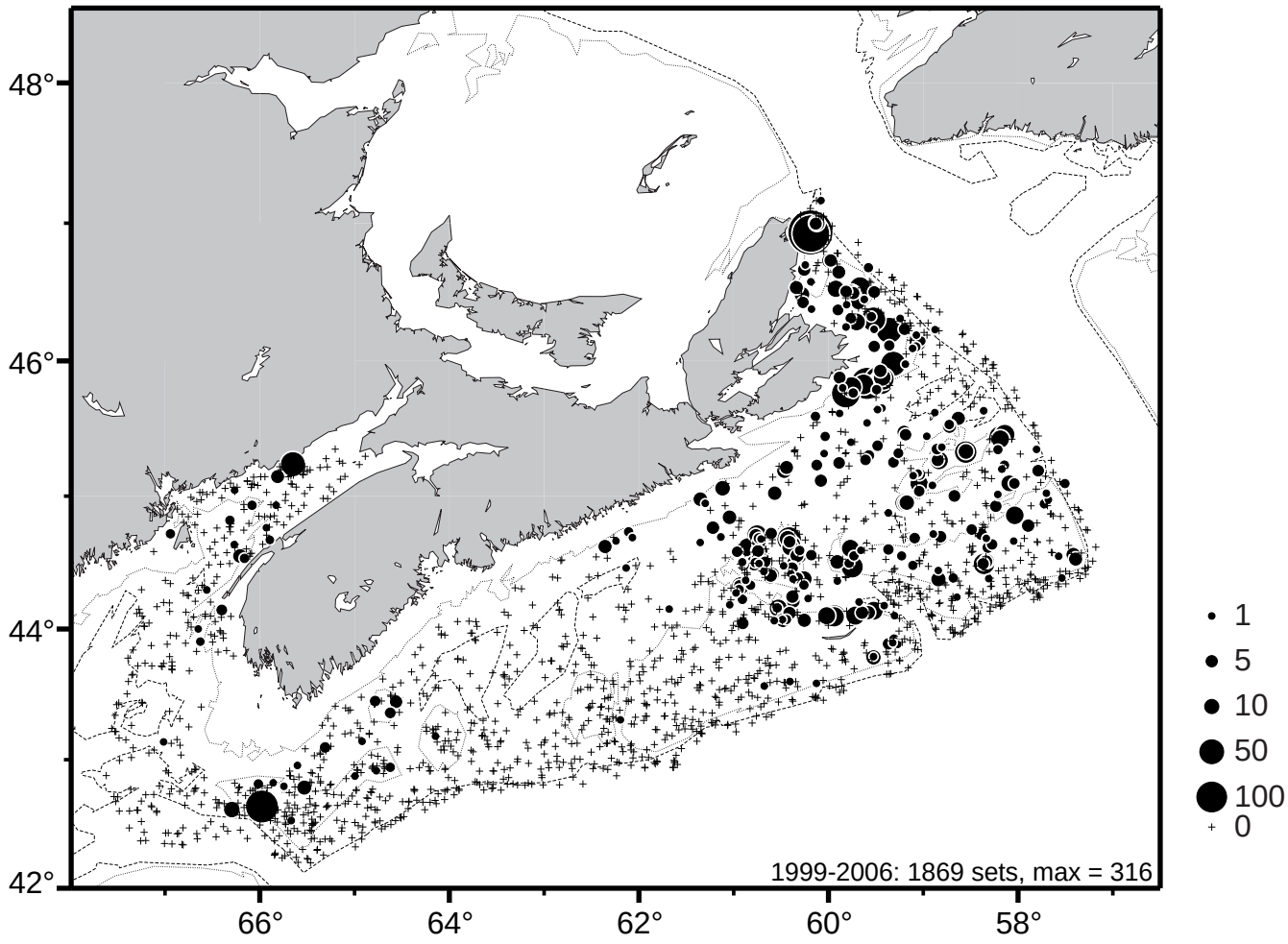

Fig. 41. Number of Lyre Crab per tow from the 1999-2006 Summer Ecosystem Surveys.

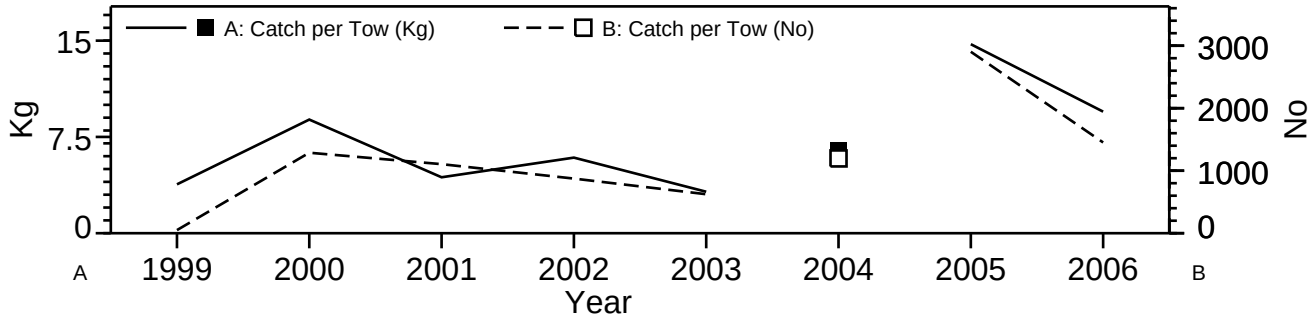

Fig. 42. Pandalus borealis stratified mean weight caught per tow, stratified mean number caught per tow from the Summer Ecosystem surveys. The catch for 2004 was sampled using the MV Teleost. It has not been calibrated, and should not be compared to the earlier time series.

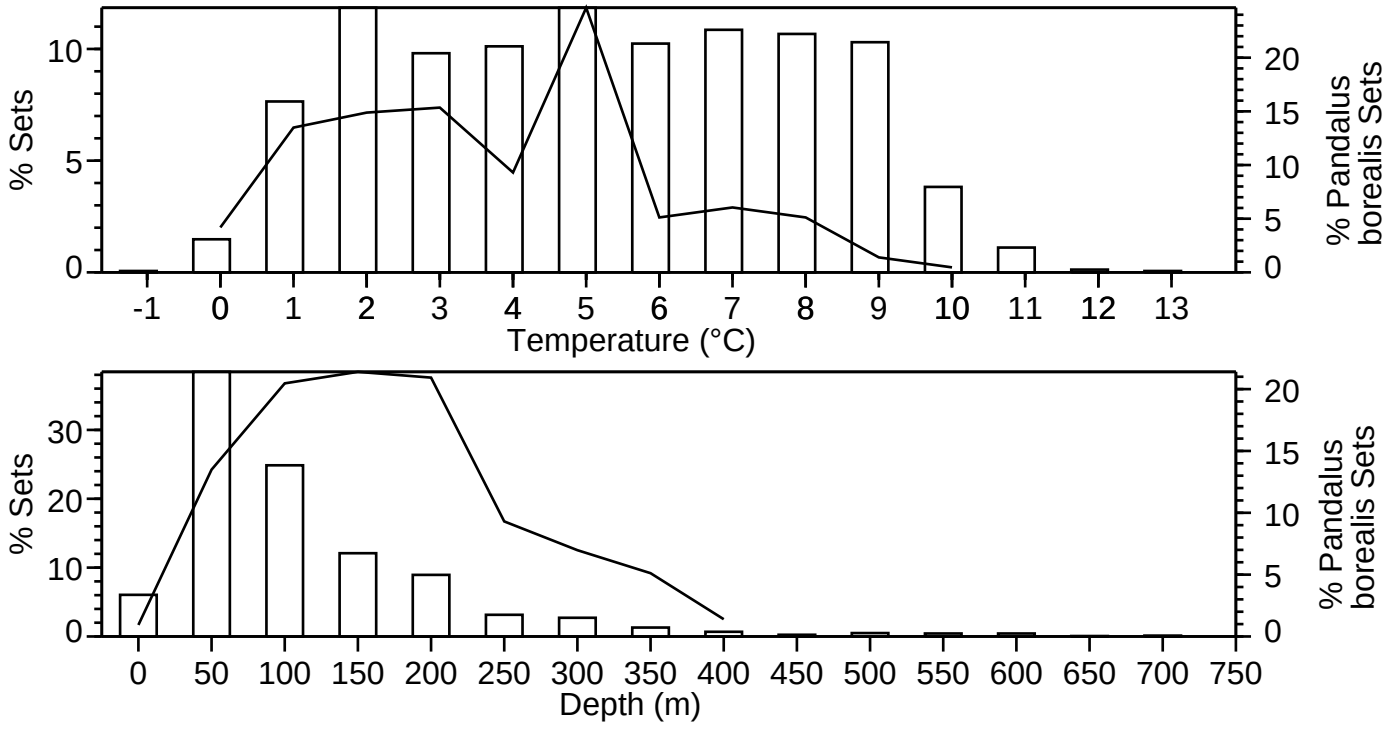

Fig. 43. Temperature and depth distribution of Pandalus borealis captured from the Summer Ecosystem surveys 1999-2006. Shown for each variable is percentage of sets with Pandalus borealis within given temperature or depth intervals (line) and percentage of all sets within different temperature or depth intervals (bar graph).

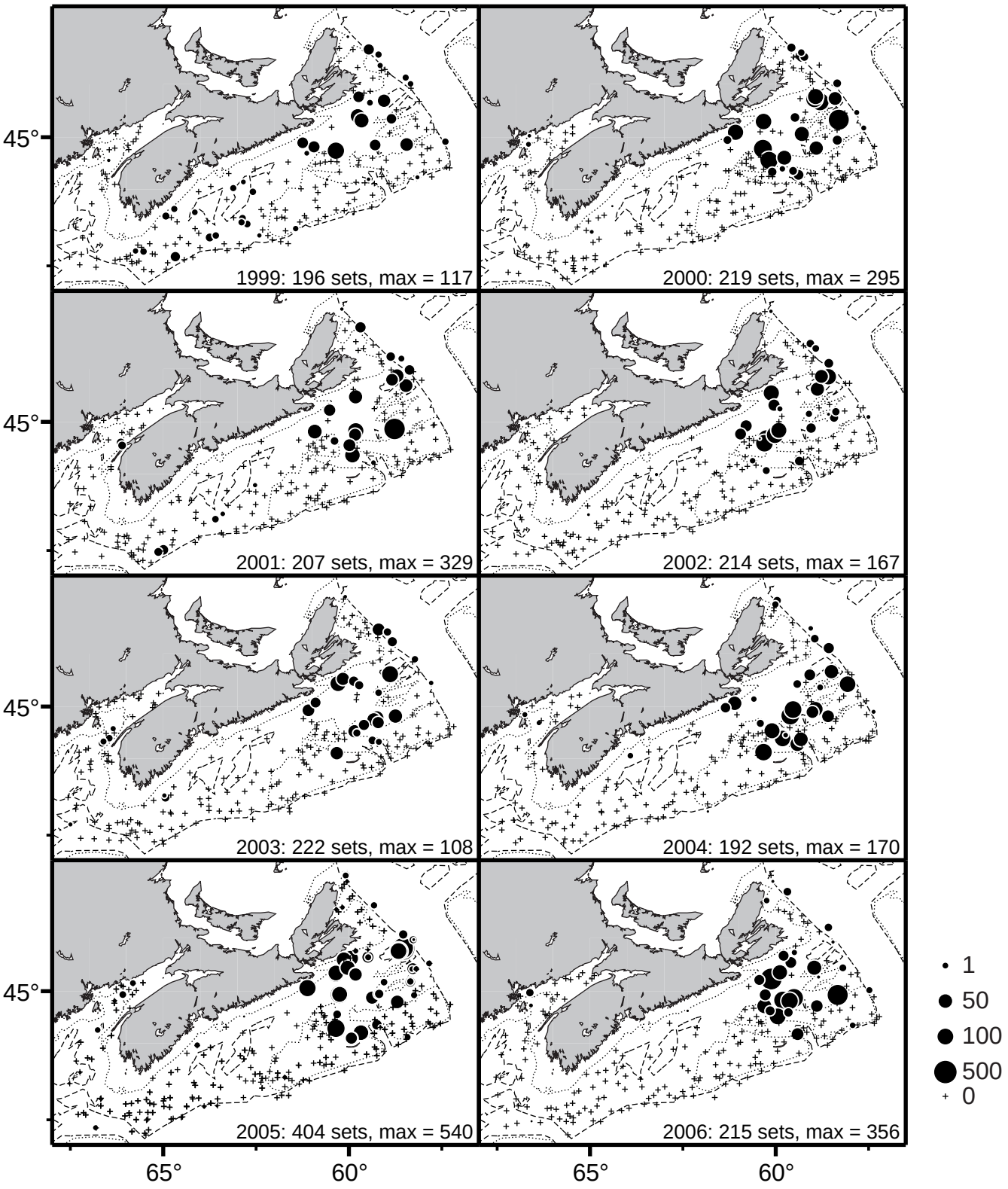

Fig. 44. Biomass (kg/tow) of Pandalus borealis from the 1999-2006 Summer Ecosystem Surveys.

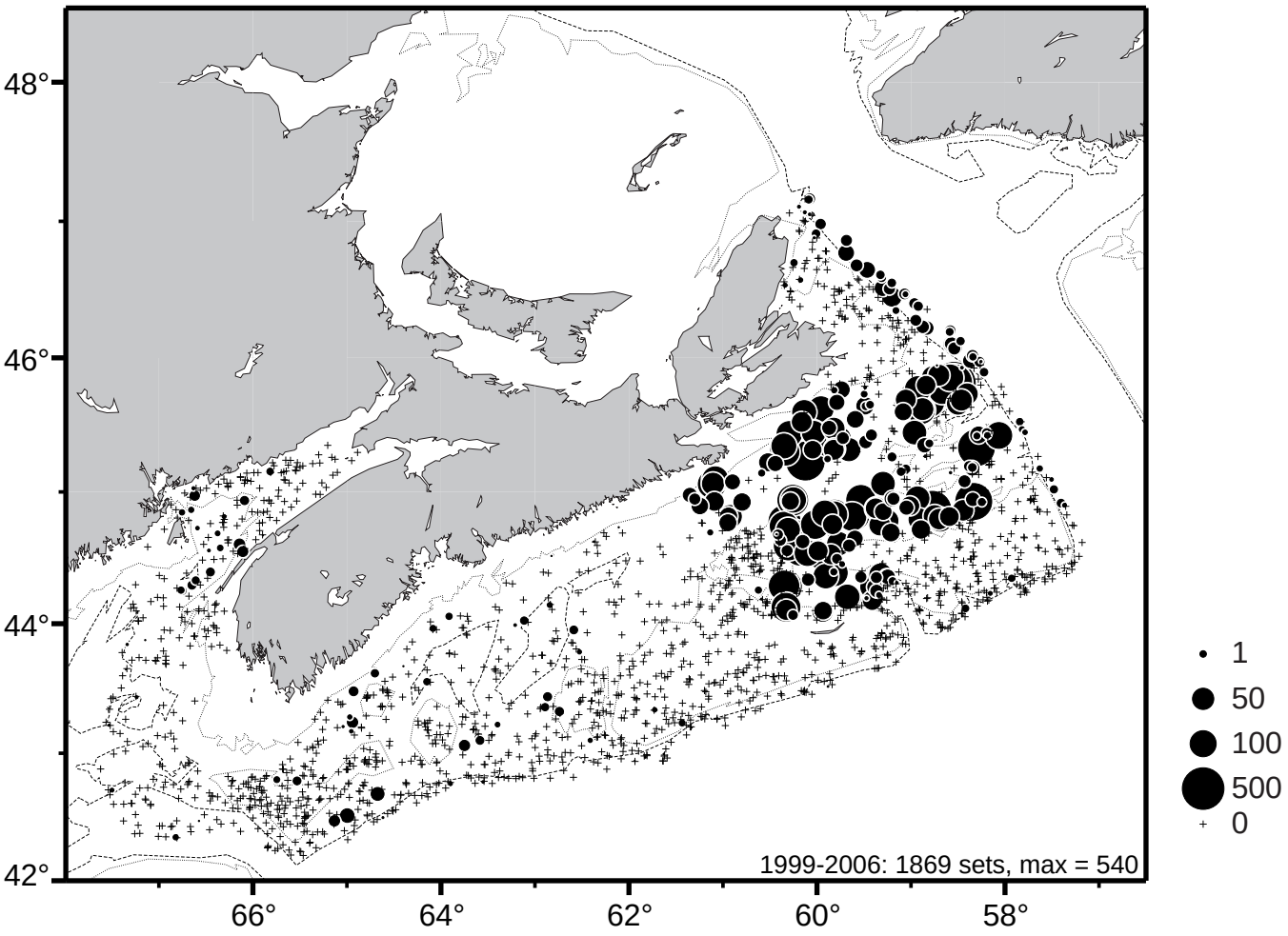

Fig. 45. Biomass (kg/tow) of Pandalus borealis from the 1999-2006 Summer Ecosystem Surveys.

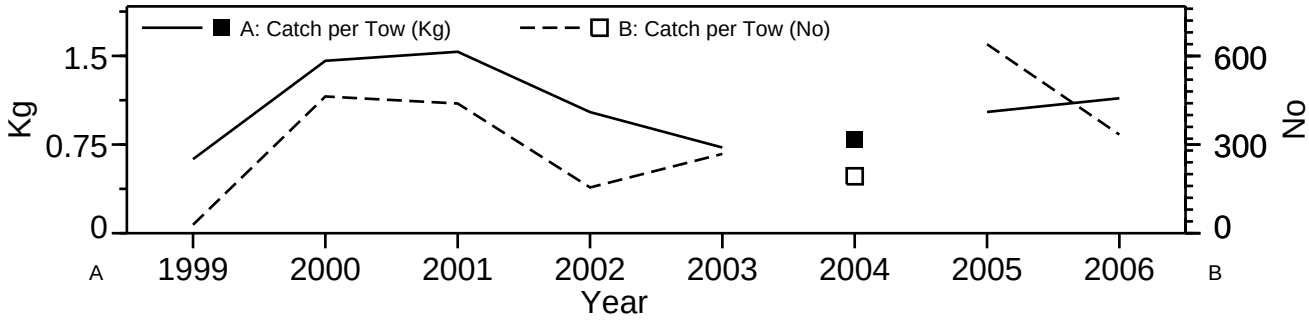

Fig. 46. Pandalus montagui stratified mean weight caught per tow, stratified mean number caught per tow from the Summer Ecosystem surveys. The catch for 2004 was sampled using the MV Teleost. It has not been calibrated, and should not be compared to the earlier time series.

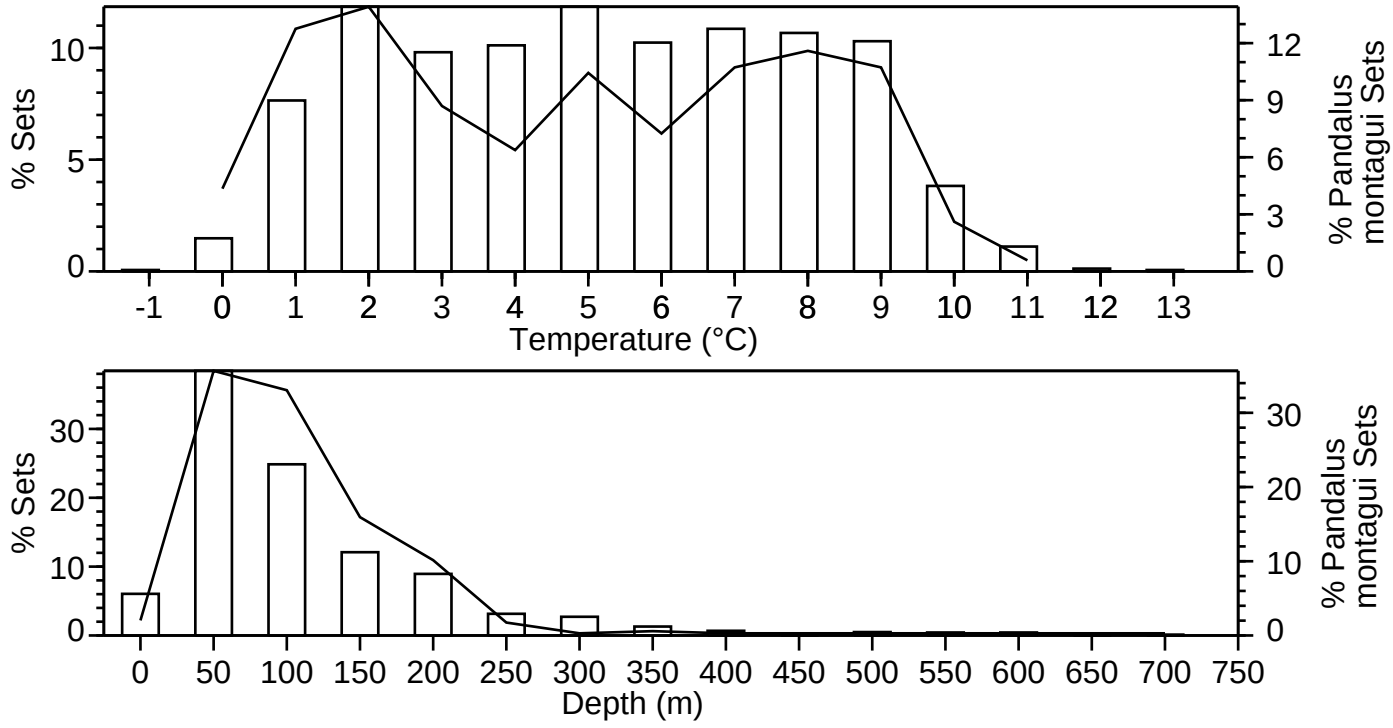

Fig. 47. Temperature and depth distribution of Pandalus montagui captured from the Summer Ecosystem surveys 1999-2006. Shown for each variable is percentage of sets with Pandalus montagui within given temperature or depth intervals (line) and percentage of all sets within different temperature or depth intervals (bar graph).

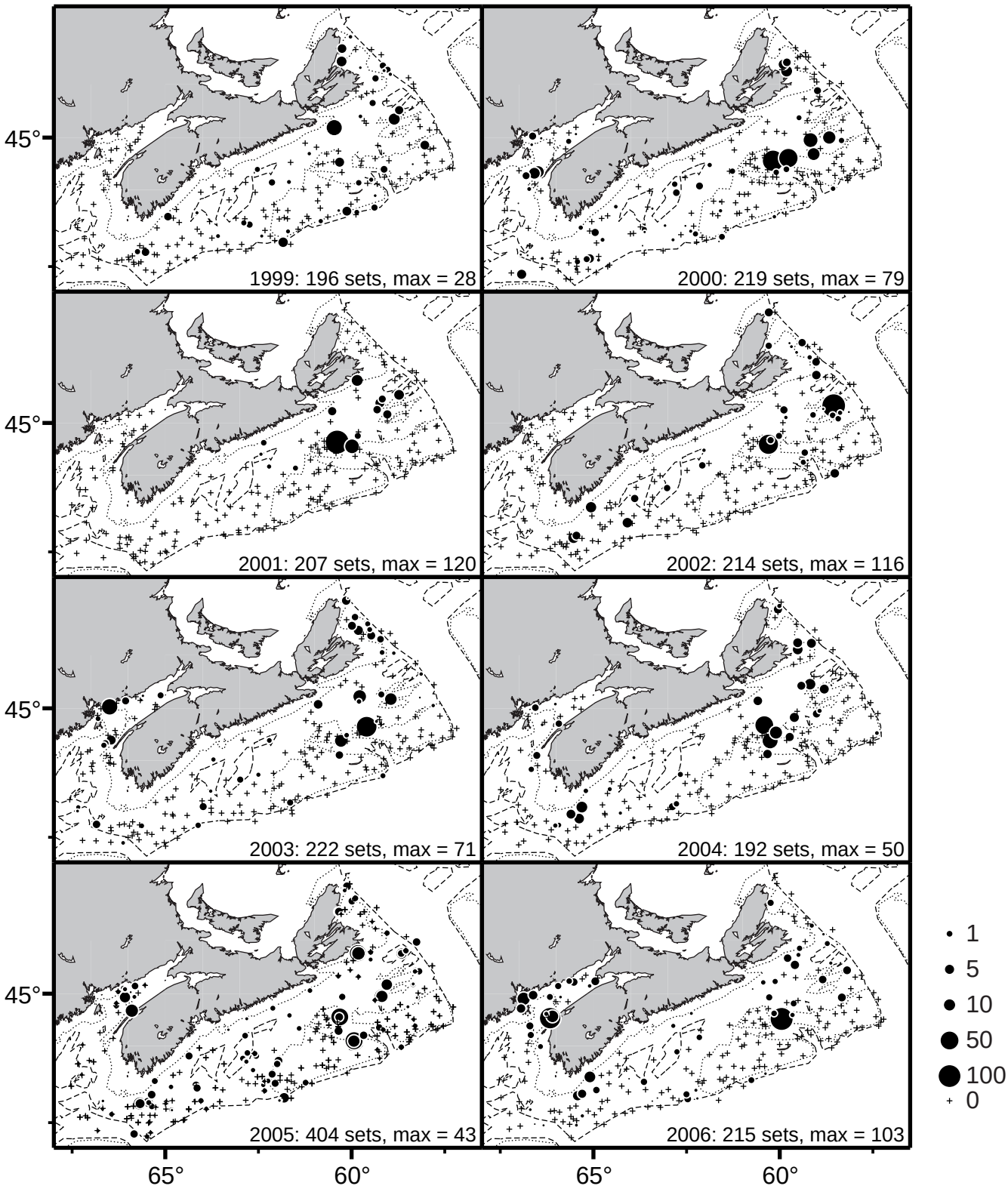

Fig. 48. Biomass (kg/tow) of Pandalus montagui from the 1999-2006 Summer Ecosystem Surveys.

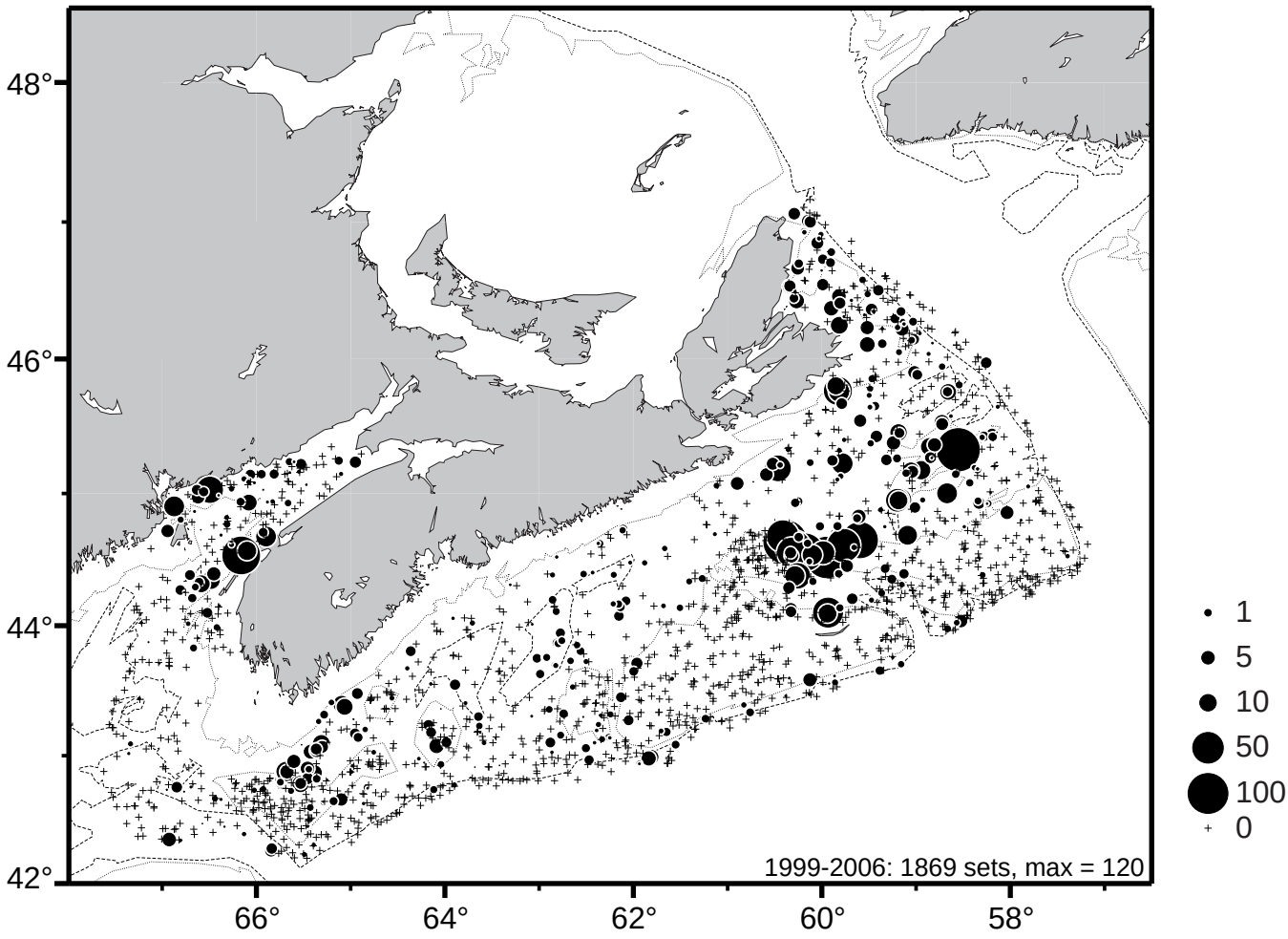

Fig. 49. Biomass (kg/tow) of Pandalus montagui from the 1999-2006 Summer Ecosystem Surveys.

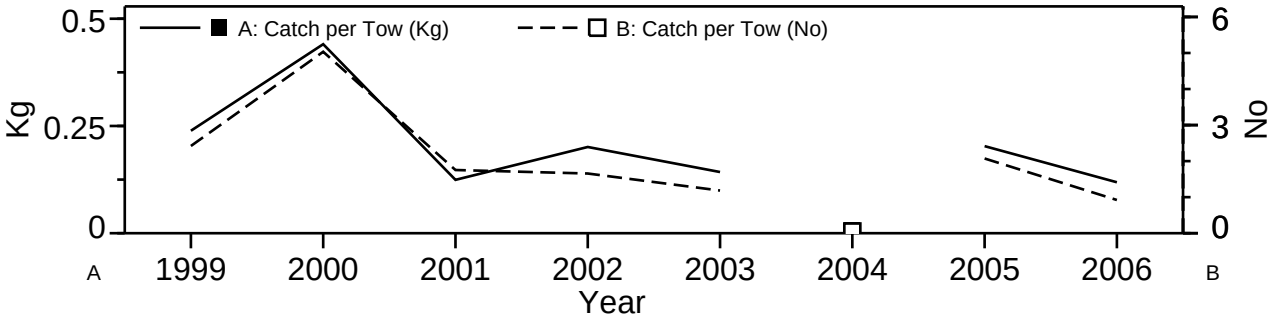

Fig. 50. Sea Scallop stratified mean weight caught per tow, stratified mean number caught per tow from the Summer Ecosystem surveys. The catch for 2004 was sampled using the MV Teleost. It has not been calibrated, and should not be compared to the earlier time series.

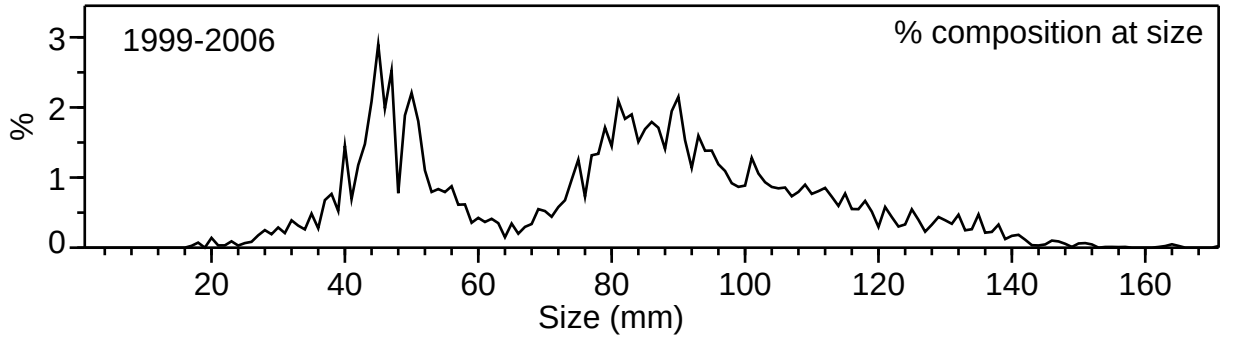

Fig. 51. Sea Scallop size frequency distribution from the Summer Ecosystem surveys.

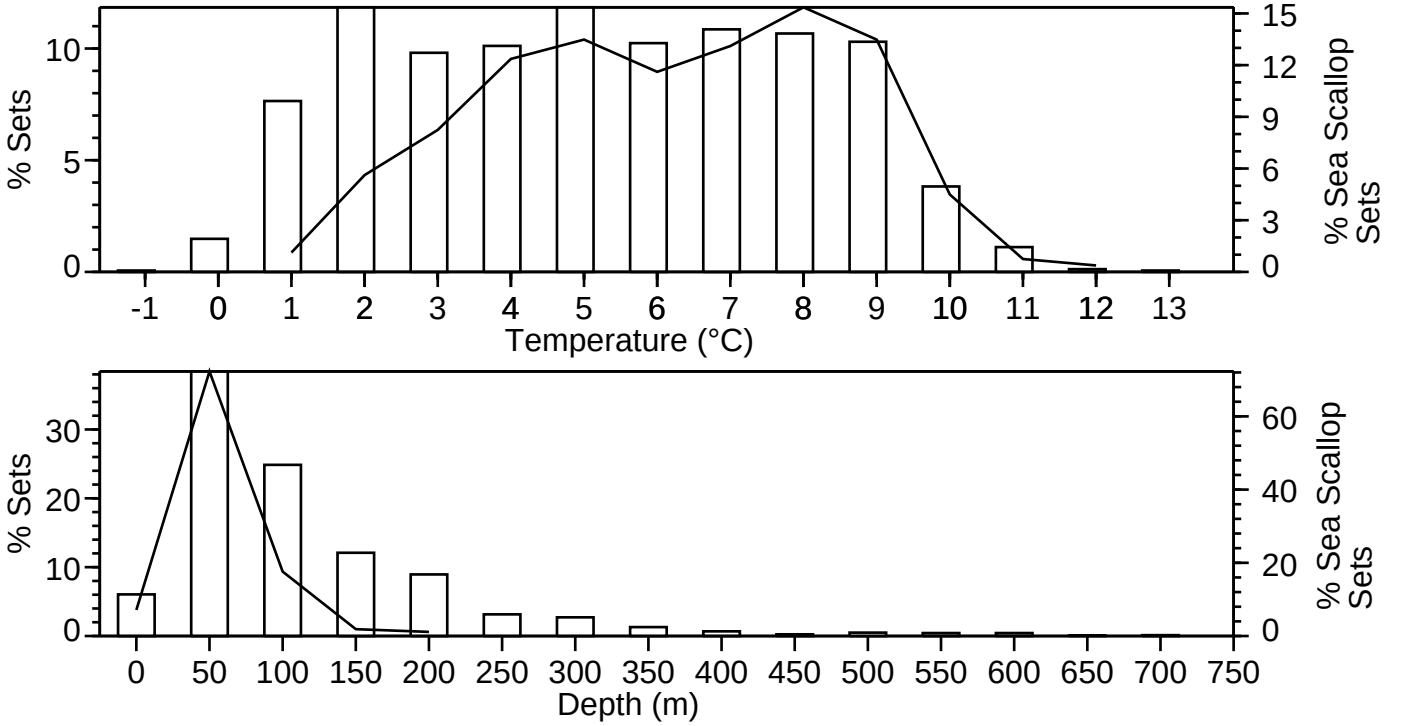

Fig. 52. Temperature and depth distribution of Sea Scallop captured from the Summer Ecosystem surveys 1999-2006. Shown for each variable is percentage of sets with Sea Scallop within given temperature or depth intervals (line) and percentage of all sets within different temperature or depth intervals (bar graph).

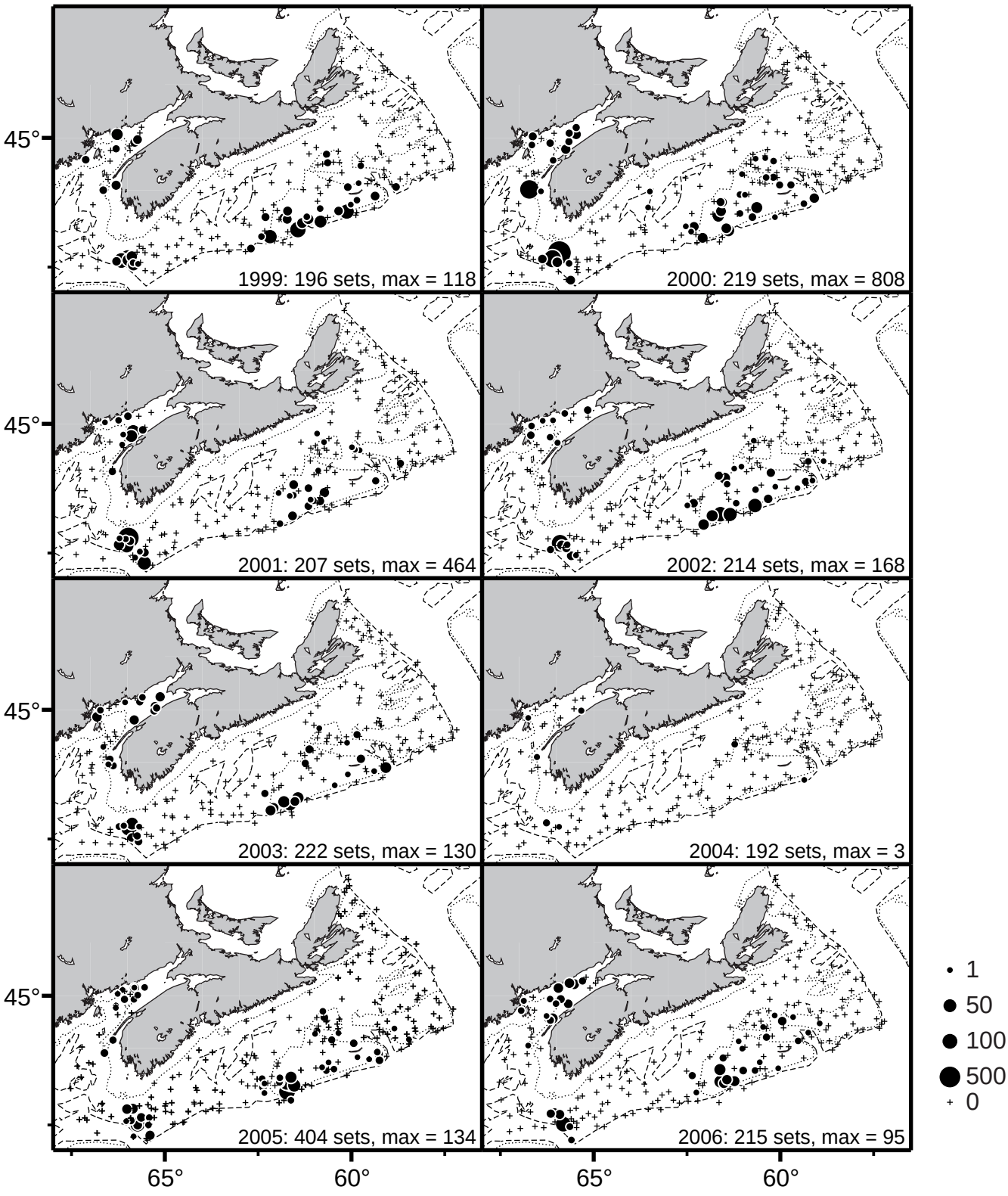

Fig. 53. Number of Sea Scallop per tow from the 1999-2006 Summer Ecosystem Surveys.

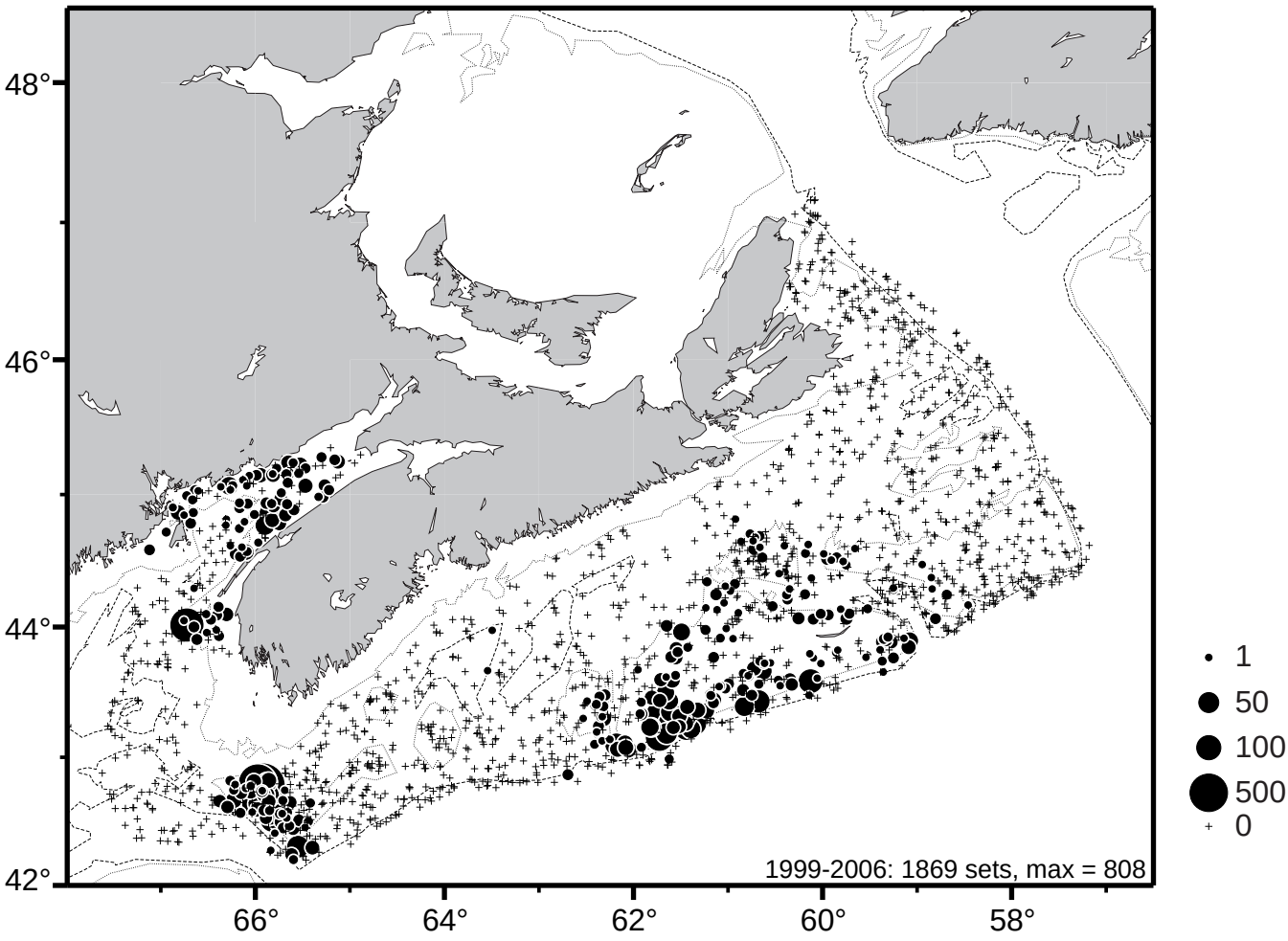

Fig. 54. Number of Sea Scallop per tow from the 1999-2006 Summer Ecosystem Surveys.

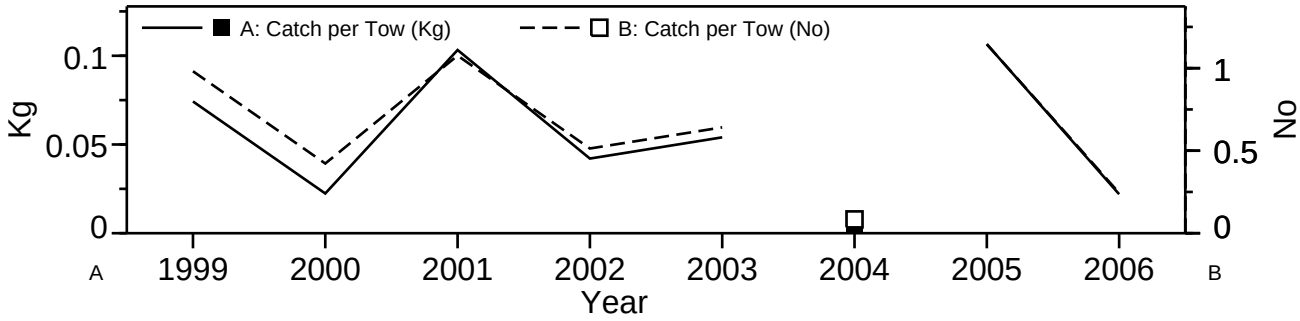

Fig. 55. Iceland Scallop stratified mean weight caught per tow, stratified mean number caught per tow from the Summer Ecosystem surveys. The catch for 2004 was sampled using the MV Teleost. It has not been calibrated, and should not be compared to the earlier time series.

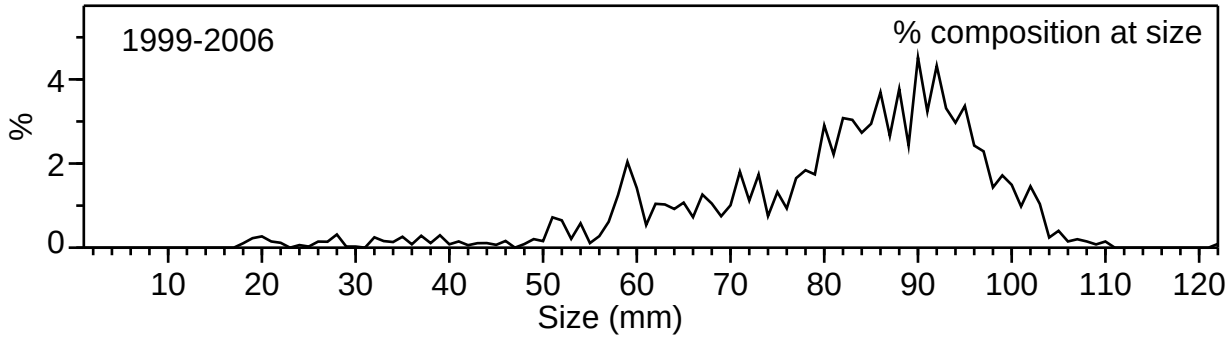

Fig. 56. Iceland Scallop size frequency distribution from the Summer Ecosystem surveys.

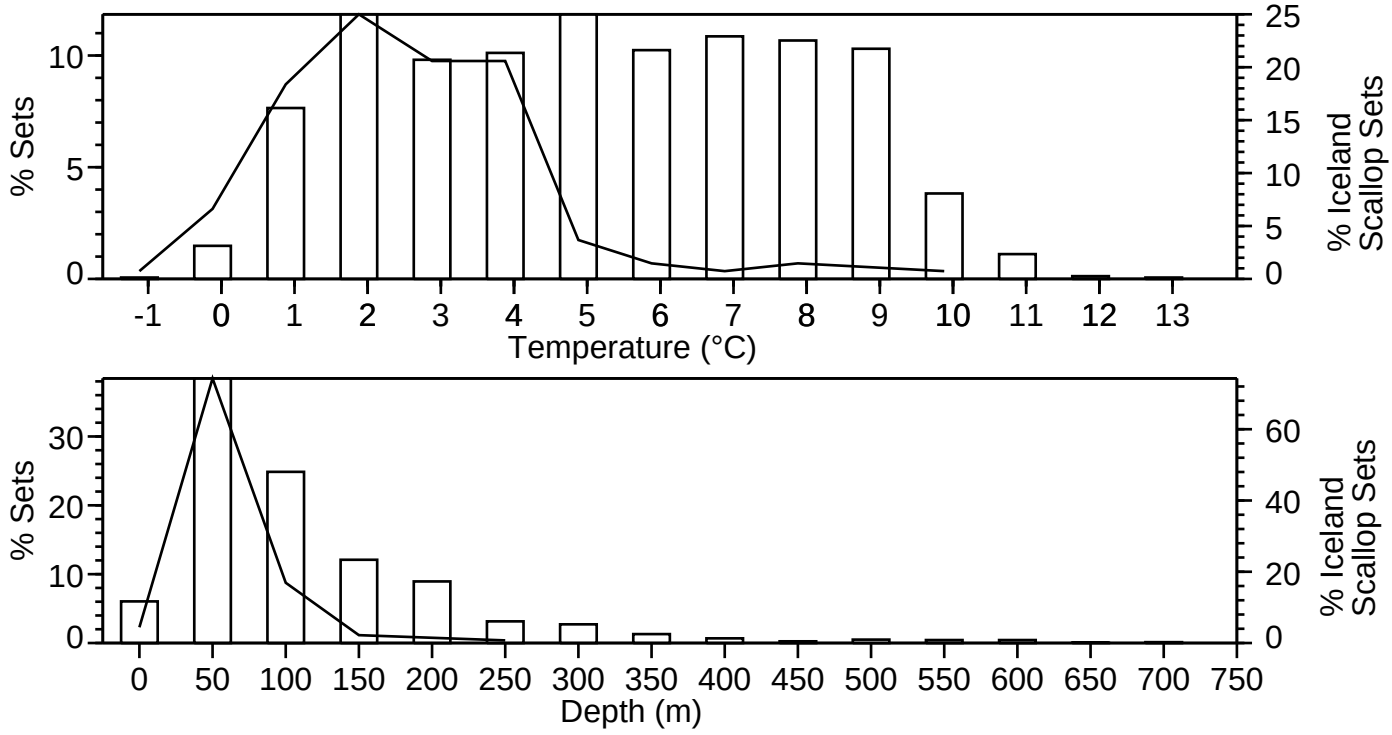

Fig. 57. Temperature and depth distribution of Iceland Scallop captured from the Summer Ecosystem surveys 1999-2006. Shown for each variable is percentage of sets with Iceland Scallop within given temperature or depth intervals (line) and percentage of all sets within different temperature or depth intervals (bar graph).

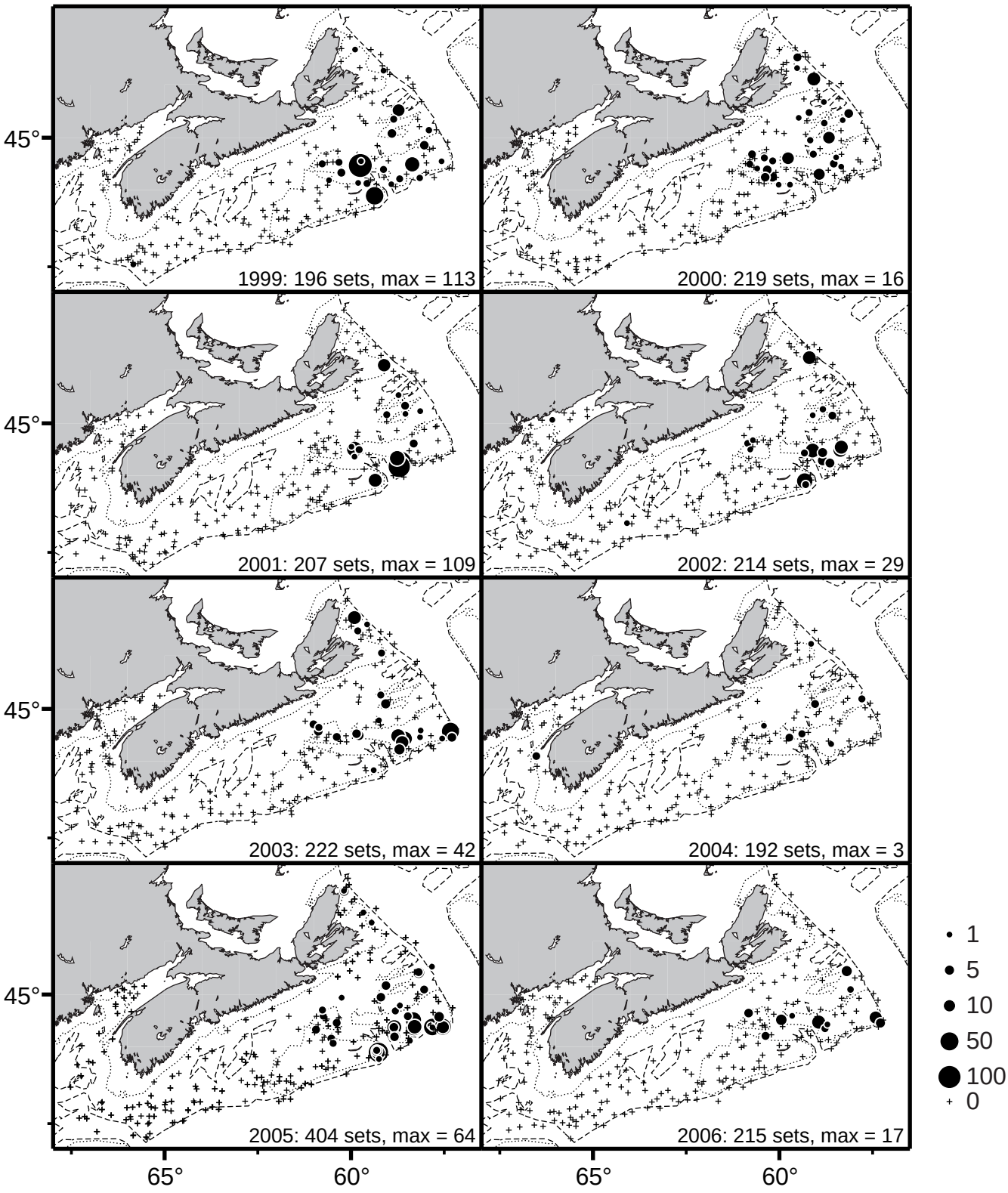

Fig. 58. Number of Iceland Scallop per tow from the 1999-2006 Summer Ecosystem Surveys.

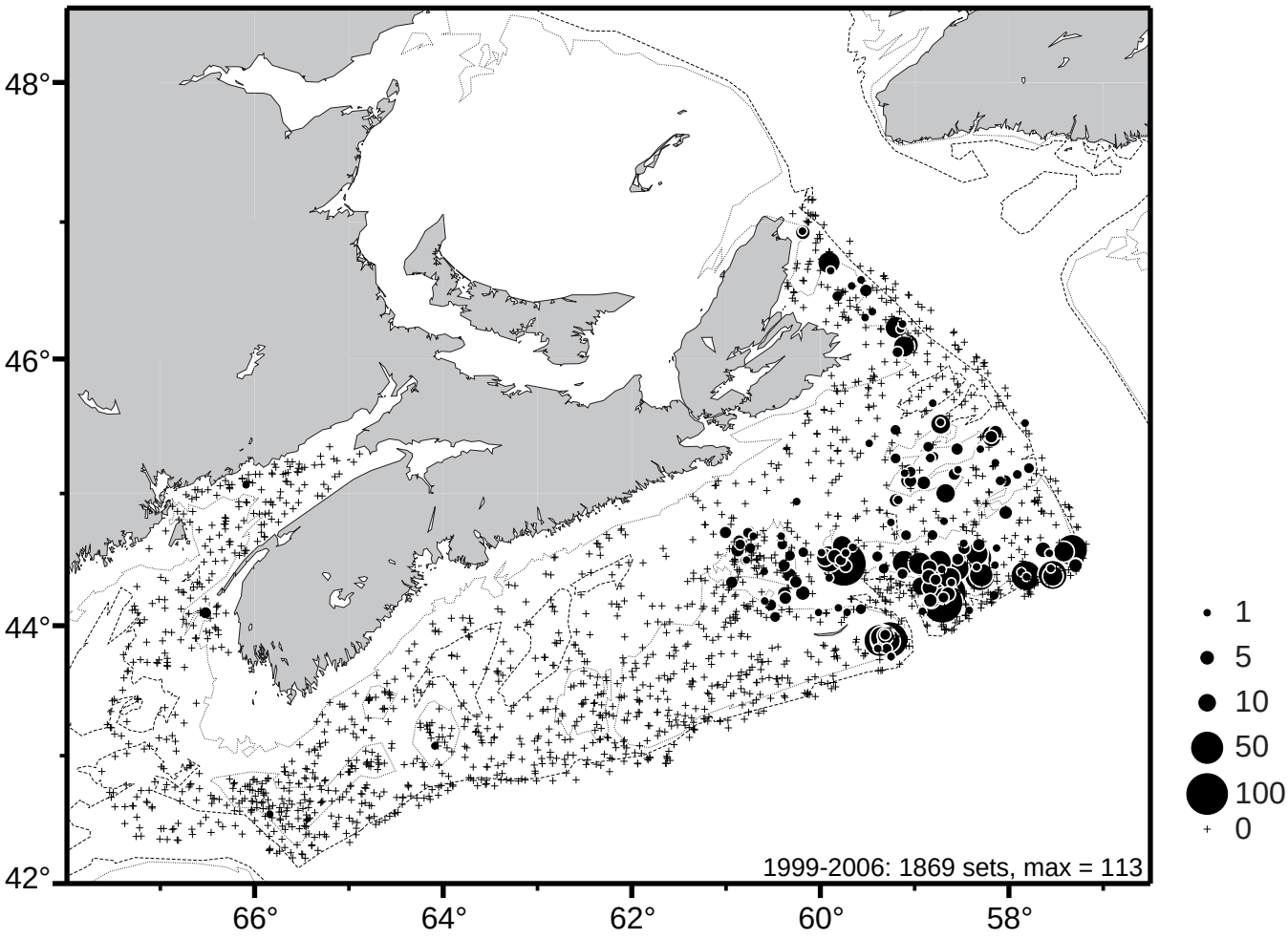

Fig. 59. Number of Iceland Scallop per tow from the 1999-2006 Summer Ecosystem Surveys.

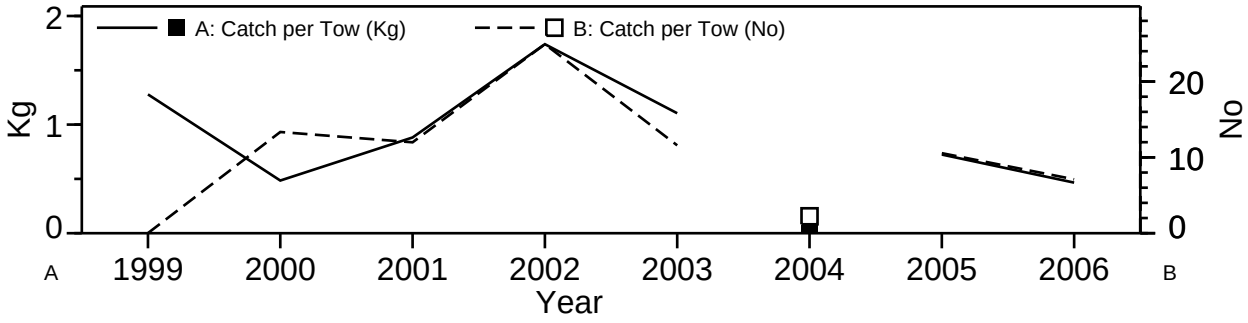

Fig. 60. Starfish stratified mean weight caught per tow, stratified mean number caught per tow from the Summer Ecosystem surveys. The catch for 2004 was sampled using the MV Teleost. It has not been calibrated, and should not be compared to the earlier time series.

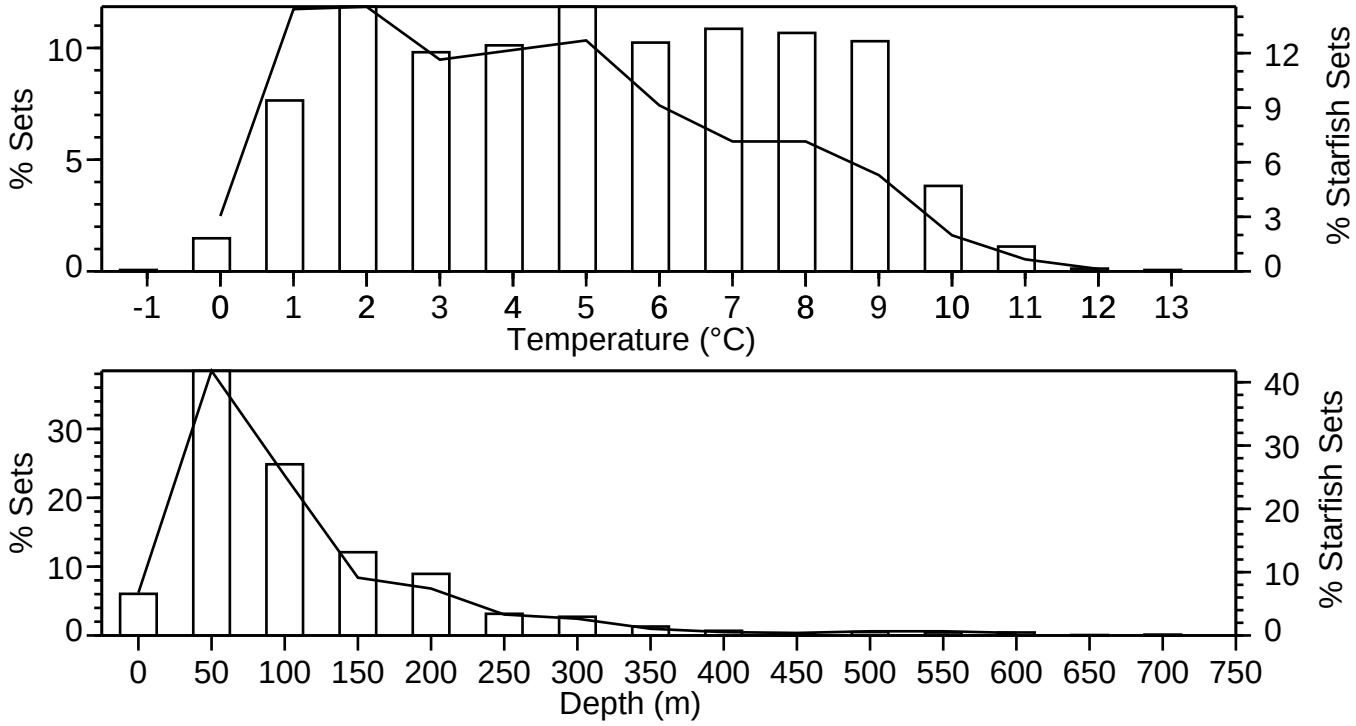

Fig. 61. Temperature and depth distribution of Starfish captured from the Summer Ecosystem surveys 1999-2006. Shown for each variable is percentage of sets with Starfish within given temperature or depth intervals (line) and percentage of all sets within different temperature or depth intervals (bar graph).

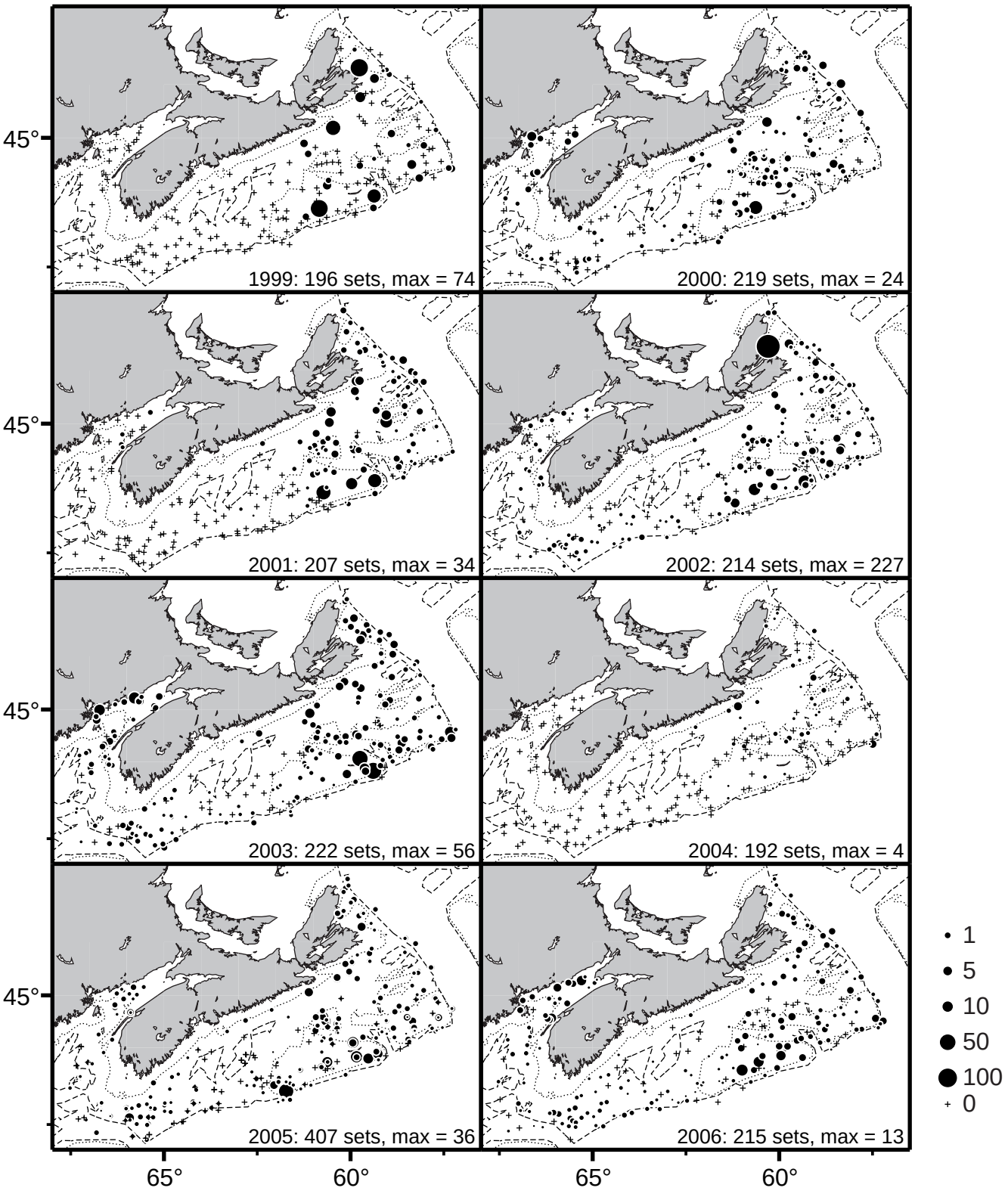

Fig. 62. Biomass (kg/tow) of Starfish from the 1999-2006 Summer Ecosystem Surveys.

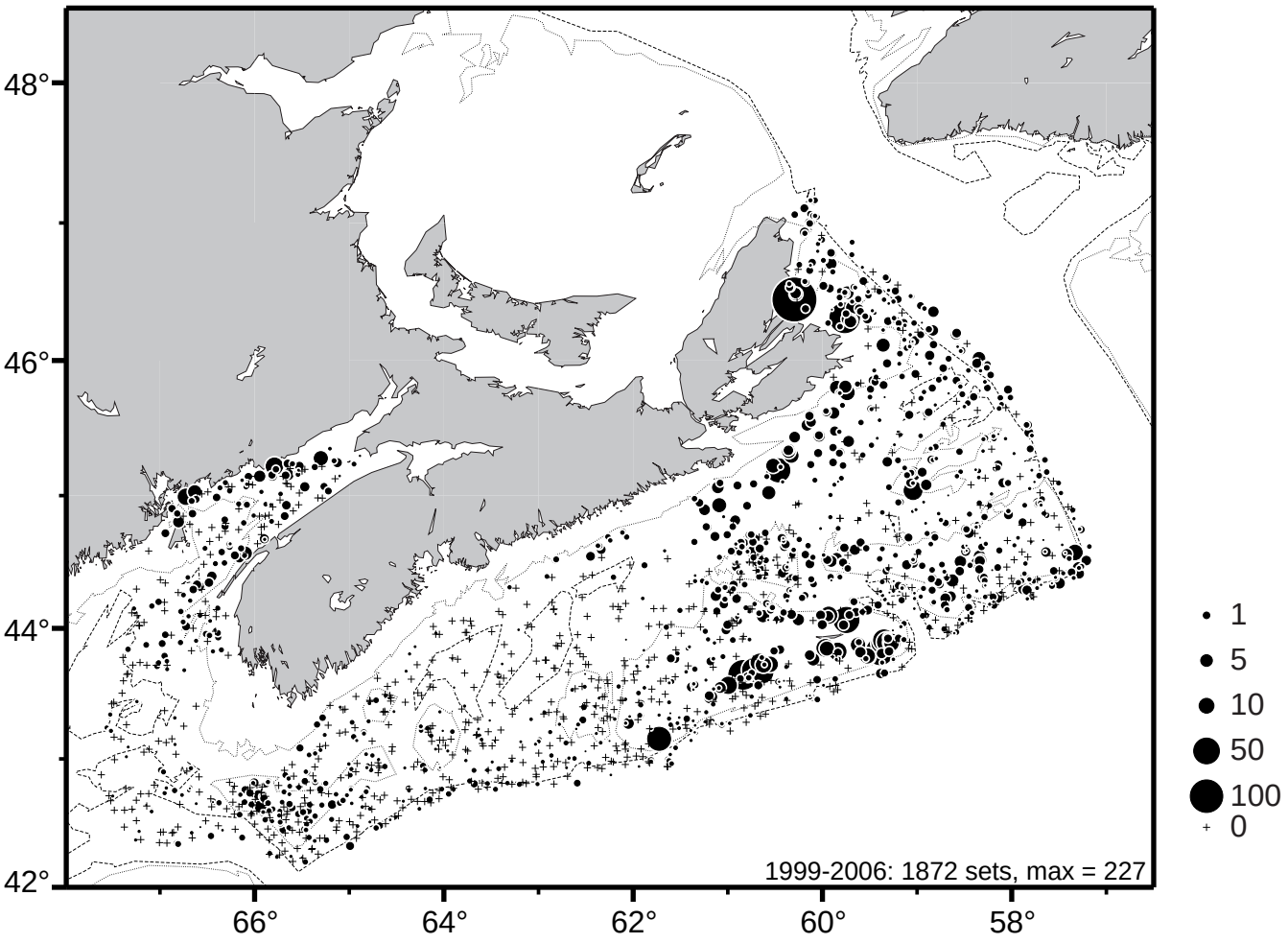

Fig. 63. Biomass (kg/tow) of Starfish from the 1999-2006 Summer Ecosystem Surveys.

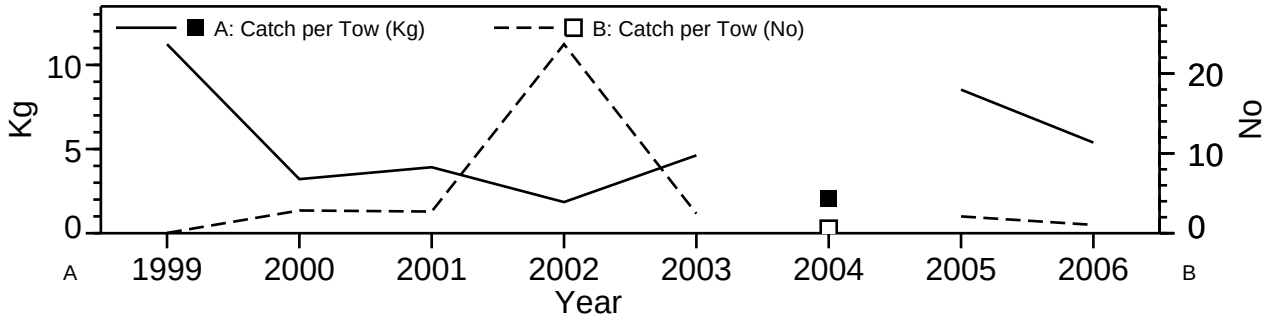

Fig. 64. Sea Cucumbers stratified mean weight caught per tow, stratified mean number caught per tow from the Summer Ecosystem surveys. The catch for 2004 was sampled using the MV Teleost. It has not been calibrated, and should not be compared to the earlier time series.

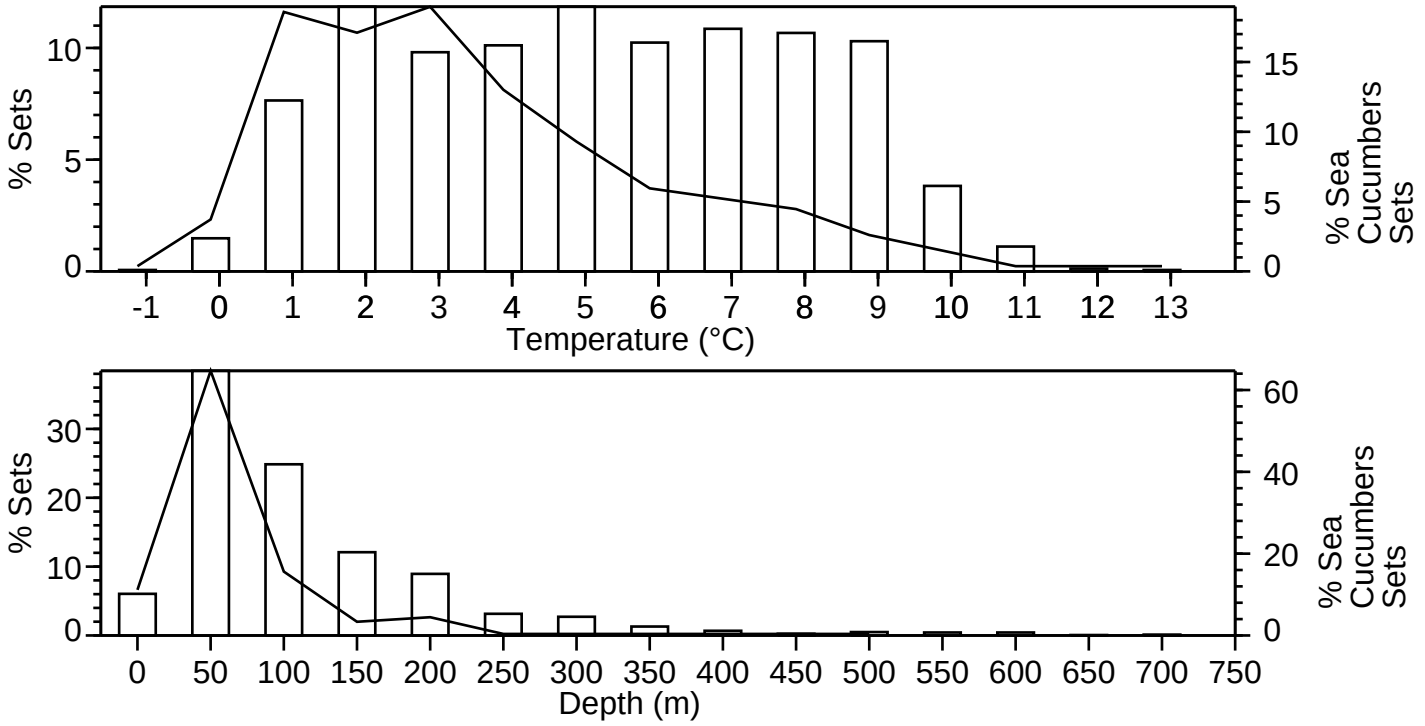

Fig. 65. Temperature and depth distribution of Sea Cucumbers captured from the Summer Ecosystem surveys 1999-2006. Shown for each variable is percentage of sets with Sea Cucumbers within given temperature or depth intervals (line) and percentage of all sets within different temperature or depth intervals (bar graph).

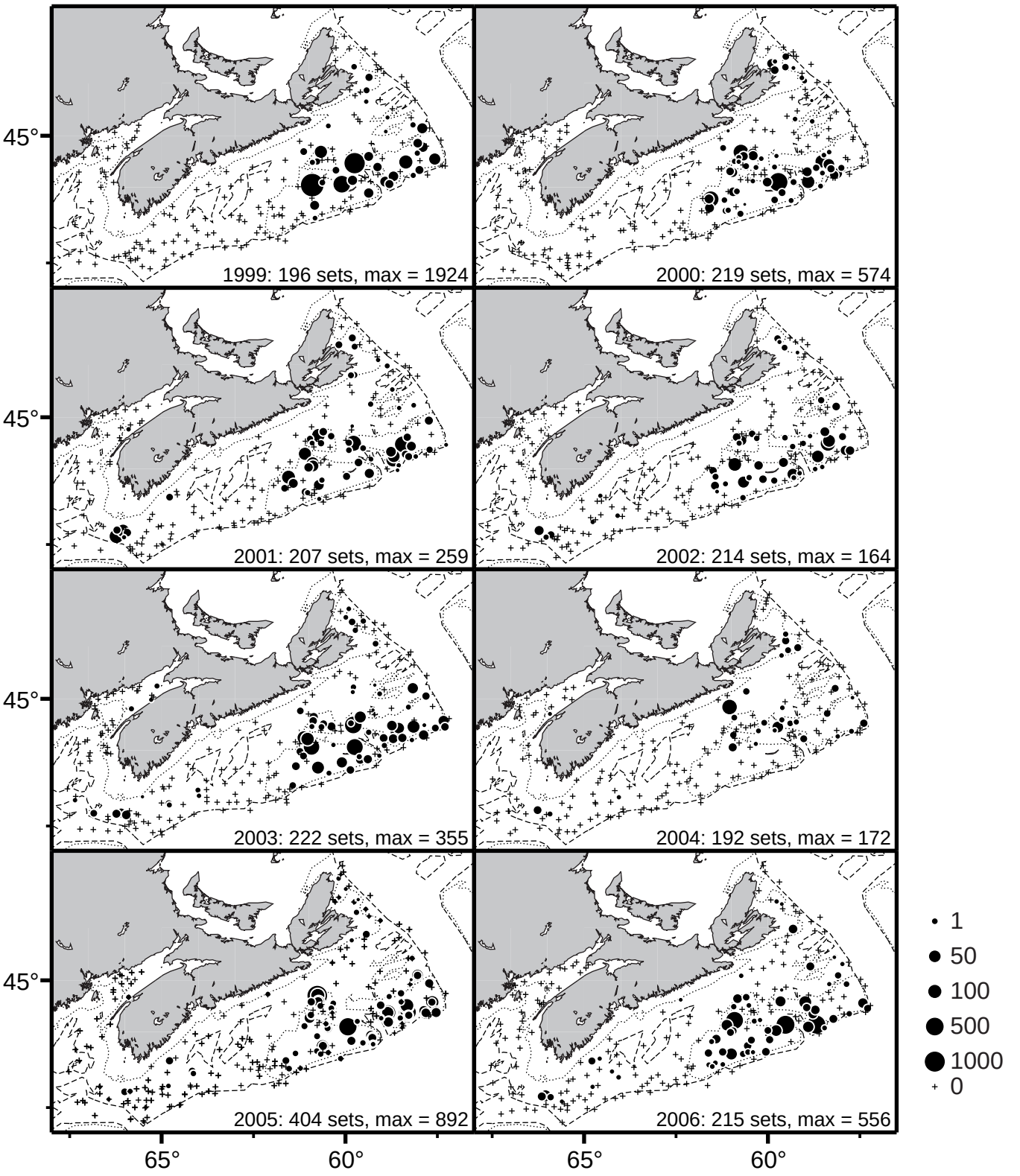

Fig. 66. Biomass (kg/tow) of Sea Cucumbers from the 1999-2006 Summer Ecosystem Surveys.

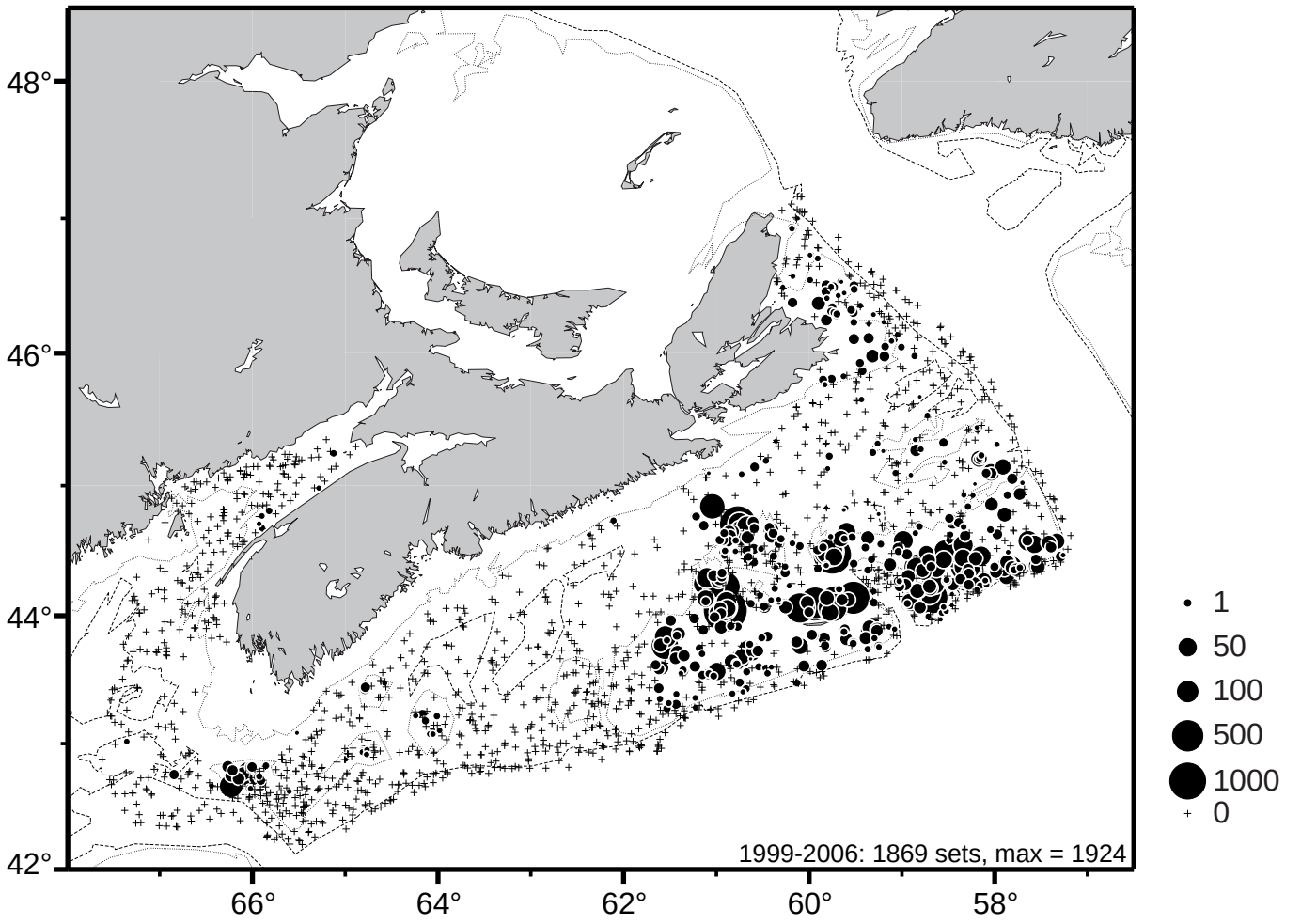

Fig. 67. Biomass (kg/tow) of Sea Cucumbers from the 1999-2006 Summer Ecosystem Surveys.

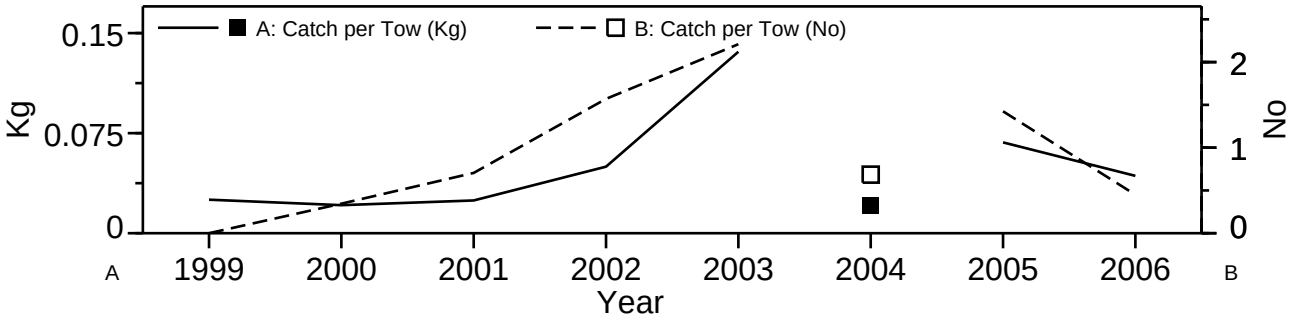

Fig. 68. Sand Dollars stratified mean weight caught per tow, stratified mean number caught per tow from the Summer Ecosystem surveys. The catch for 2004 was sampled using the MV Teleost. It has not been calibrated, and should not be compared to the earlier time series.

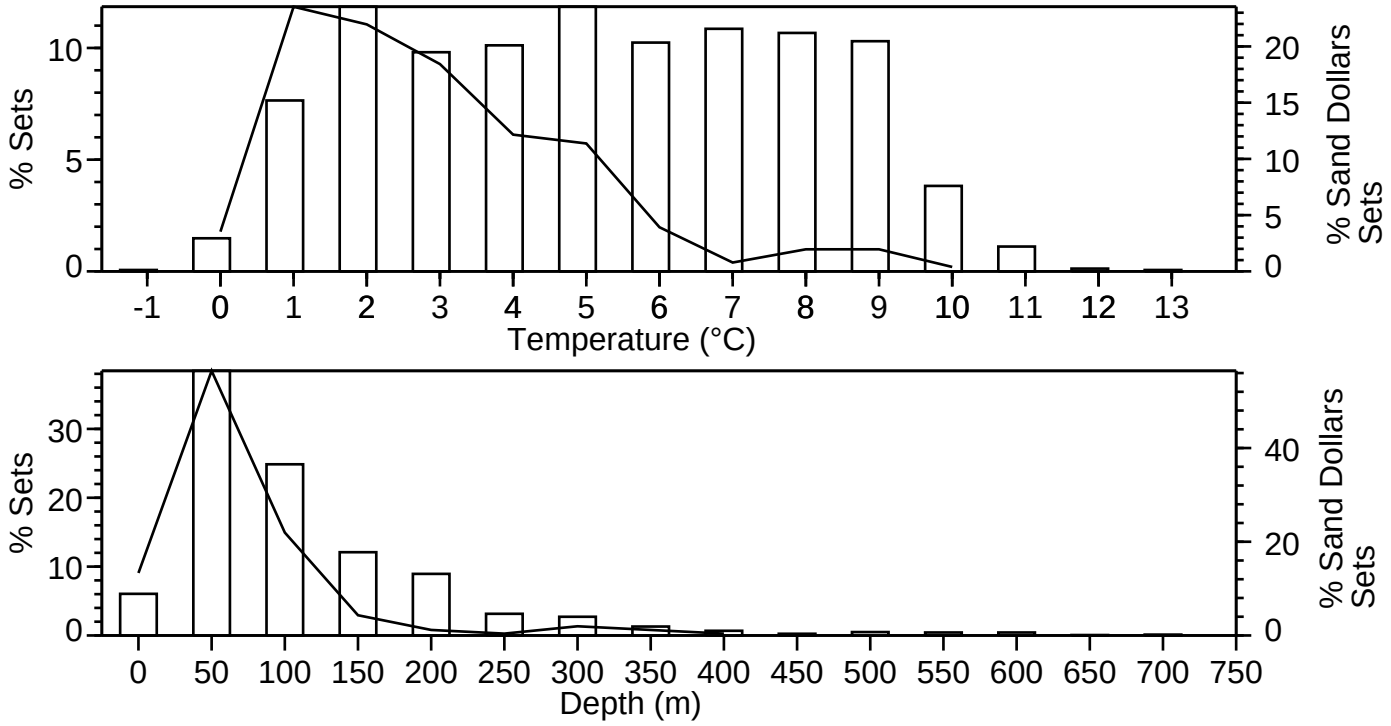

Fig. 69. Temperature and depth distribution of Sand Dollars captured from the Summer Ecosystem surveys 1999-2006. Shown for each variable is percentage of sets with Sand Dollars within given temperature or depth intervals (line) and percentage of all sets within different temperature or depth intervals (bar graph).

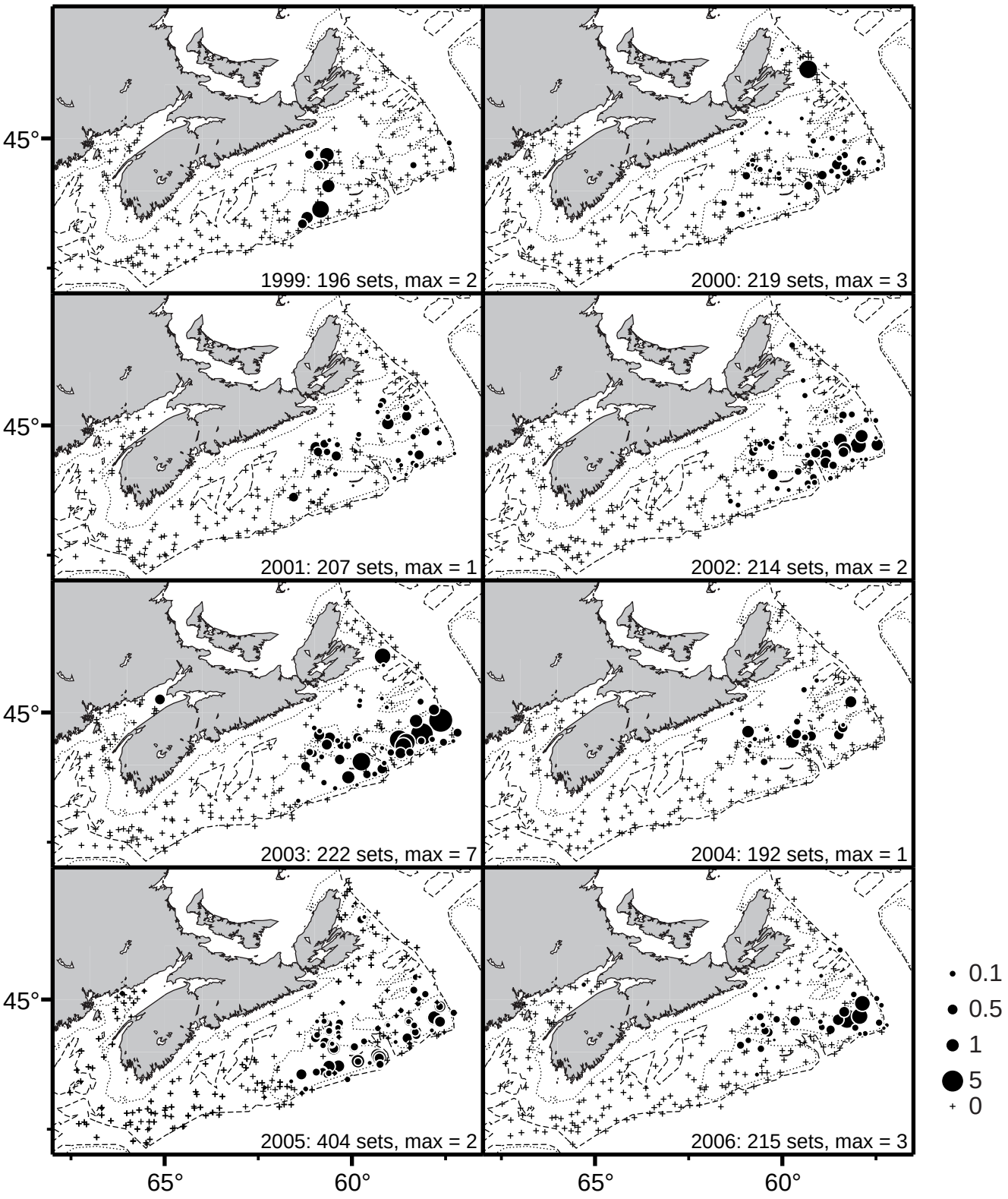

Fig. 70. Biomass (kg/tow) of Sand Dollars from the 1999-2006 Summer Ecosystem Surveys.

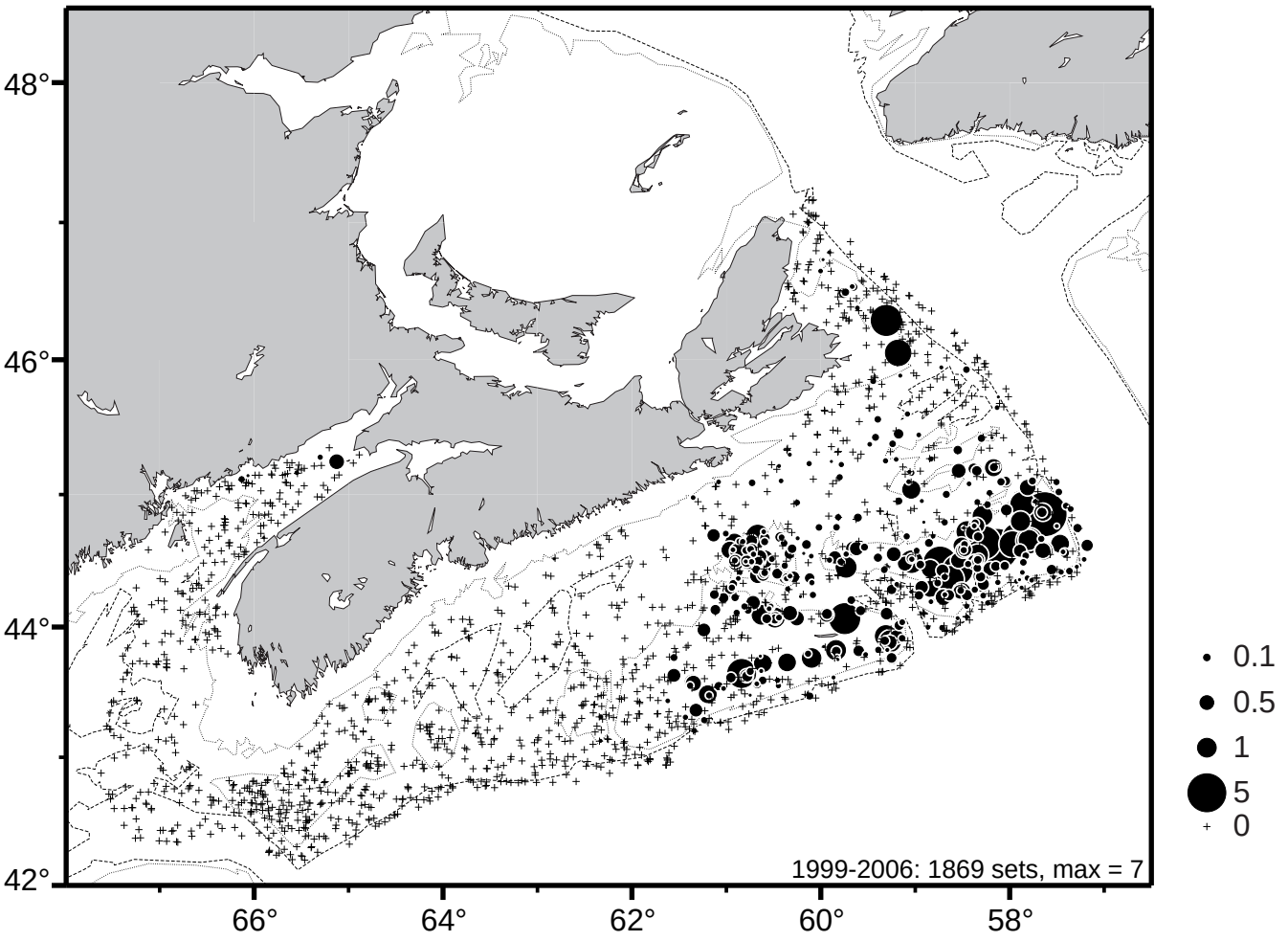

Fig. 71. Biomass (kg/tow) of Sand Dollars from the 1999-2006 Summer Ecosystem Surveys.

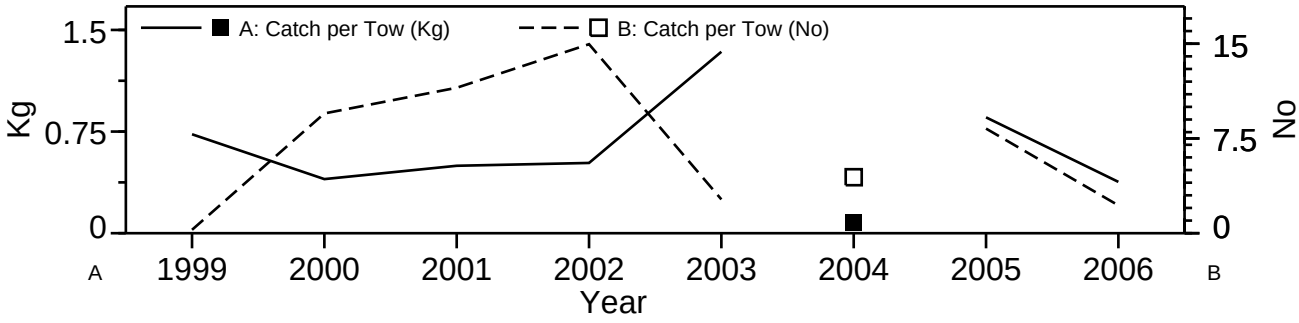

Fig. 72. Sea Urchins stratified mean weight caught per tow, stratified mean number caught per tow from the Summer Ecosystem surveys. The catch for 2004 was sampled using the MV Teleost. It has not been calibrated, and should not be compared to the earlier time series.

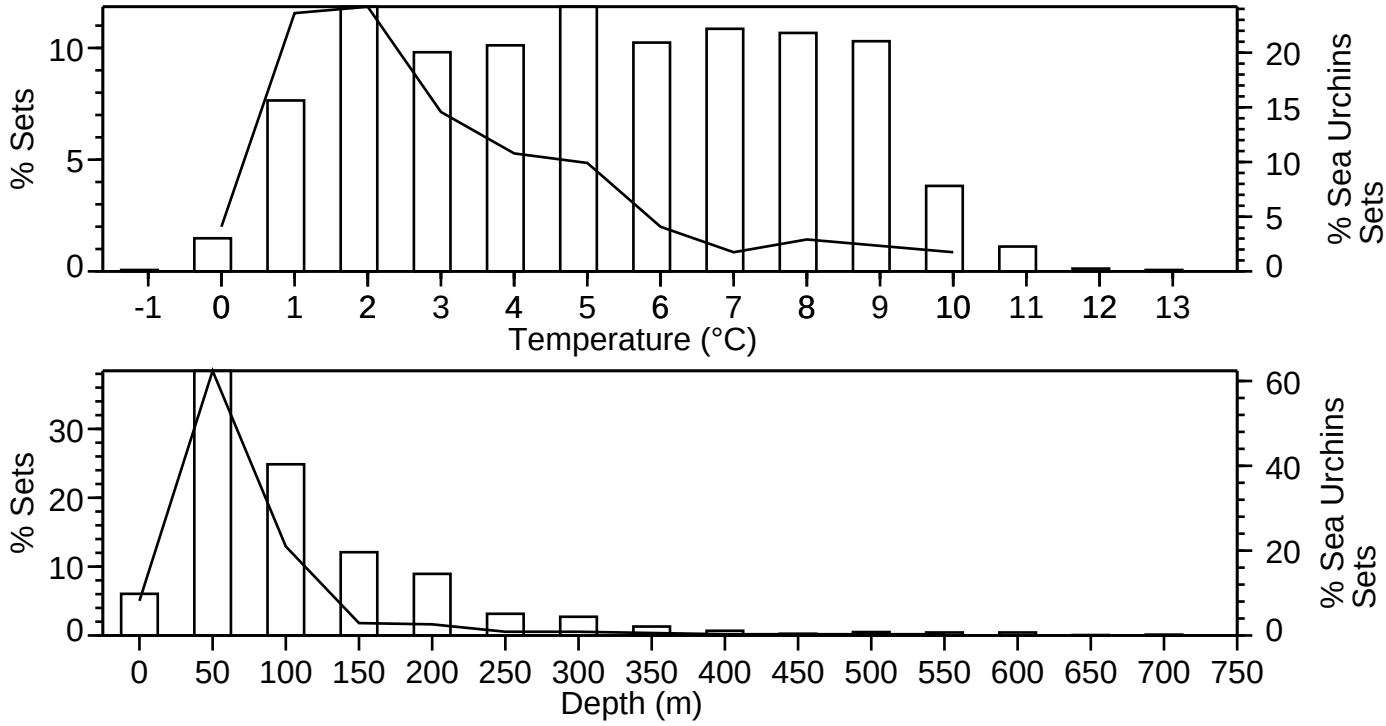

Fig. 73. Temperature and depth distribution of Sea Urchins captured from the Summer Ecosystem surveys 1999-2006. Shown for each variable is percentage of sets with Sea Urchins within given temperature or depth intervals (line) and percentage of all sets within different temperature or depth intervals (bar graph).

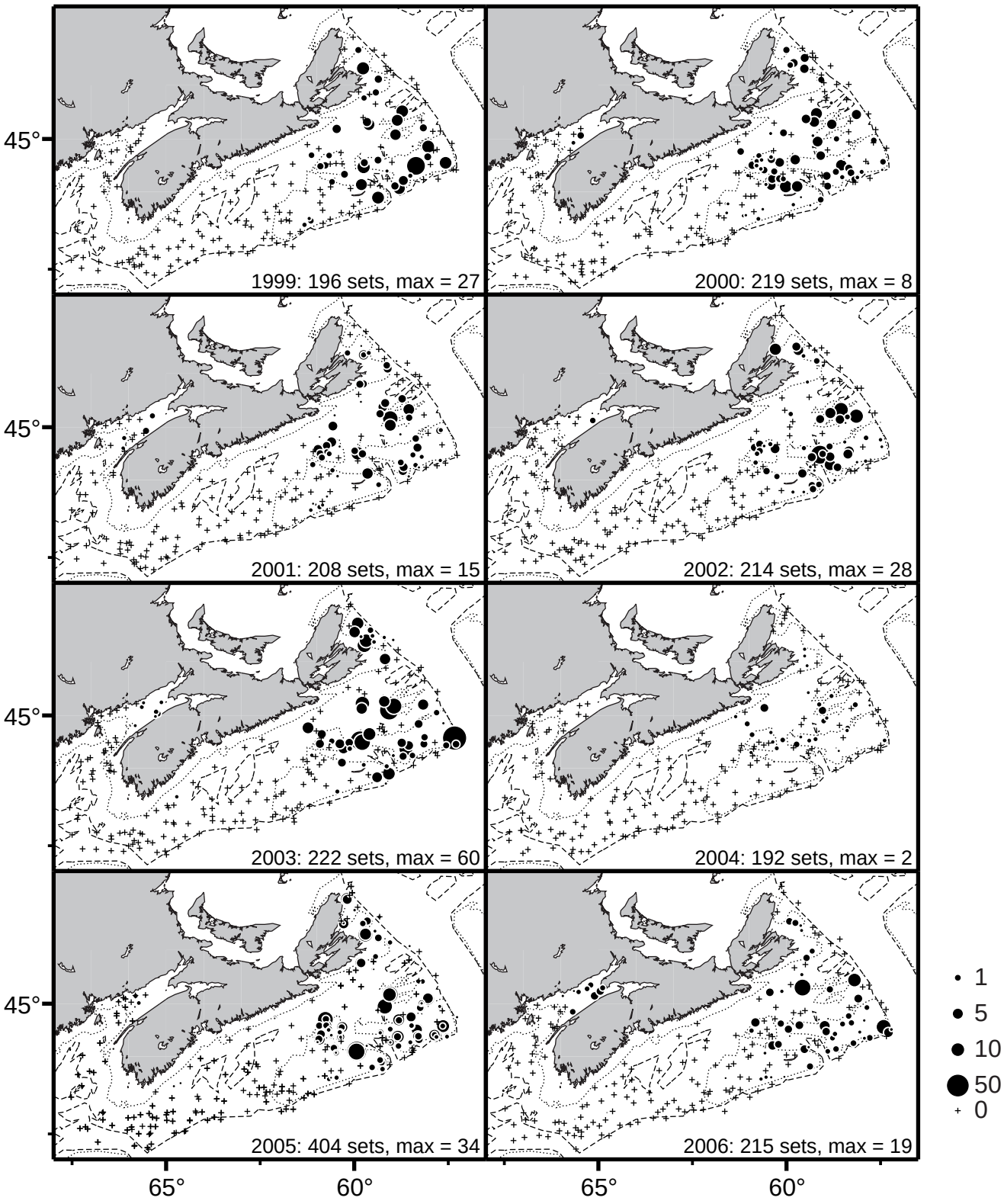

Fig. 74. Biomass (kg/tow) of Sea Urchins from the 1999-2006 Summer Ecosystem Surveys.

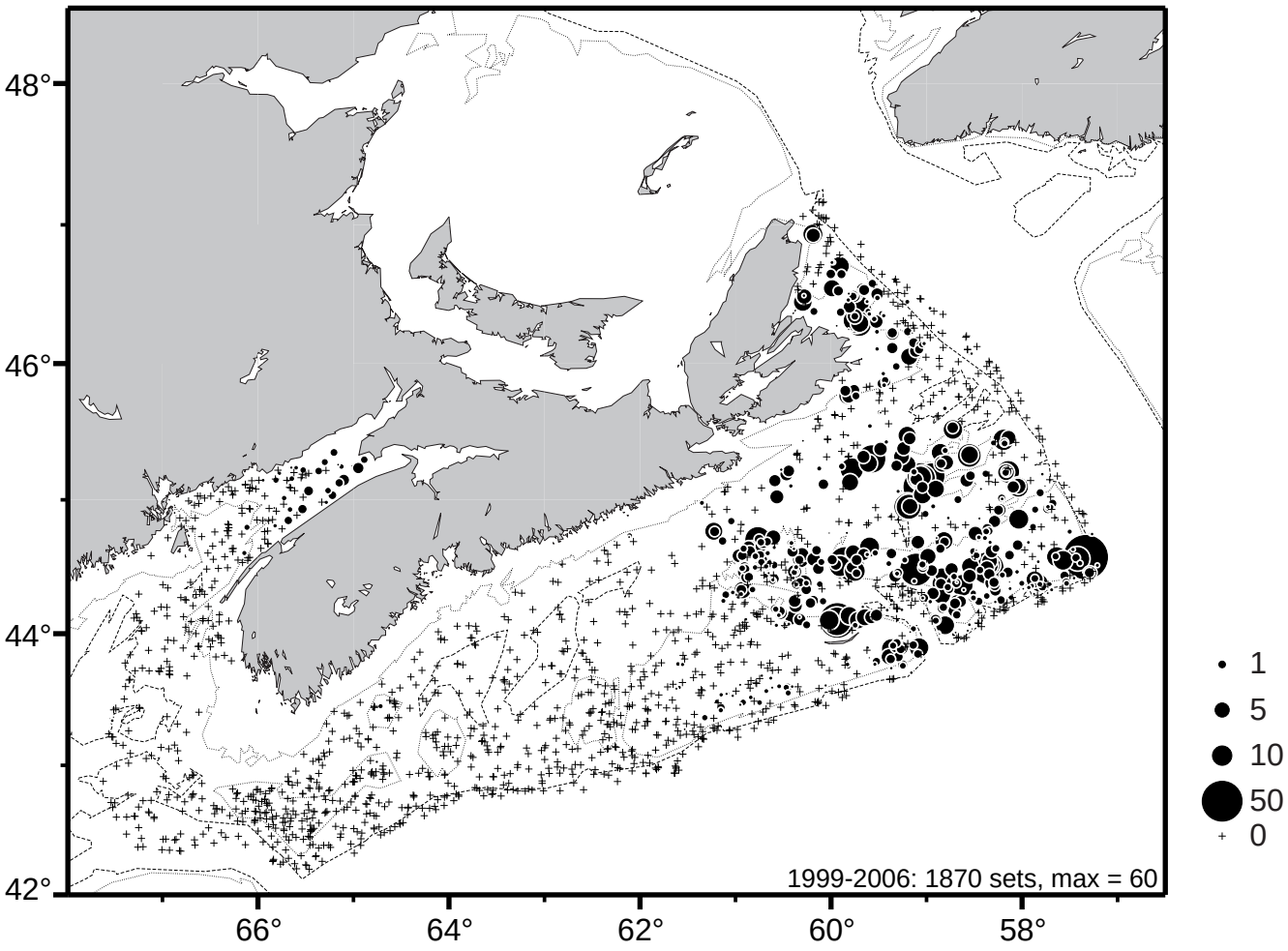

Fig. 75. Biomass (kg/tow) of Sea Urchins from the 1999-2006 Summer Ecosystem Surveys.

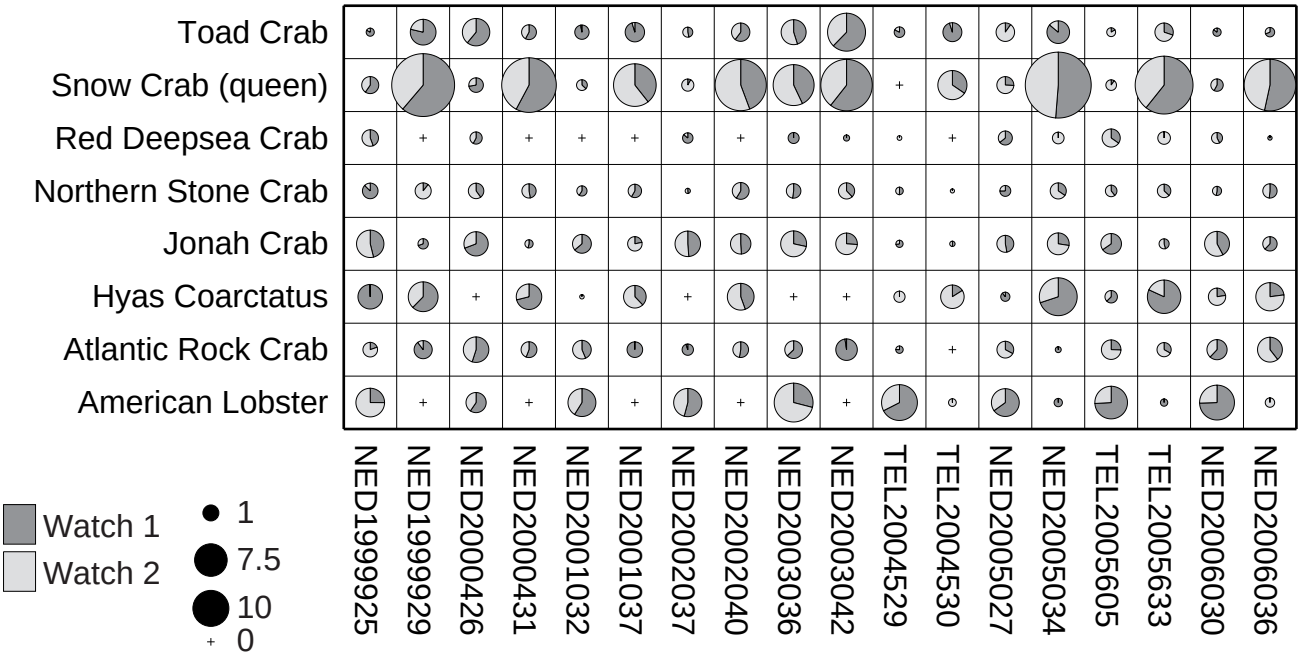

Fig. 76. Number caught per tow by Watch from the Summer Ecosystem surveys.

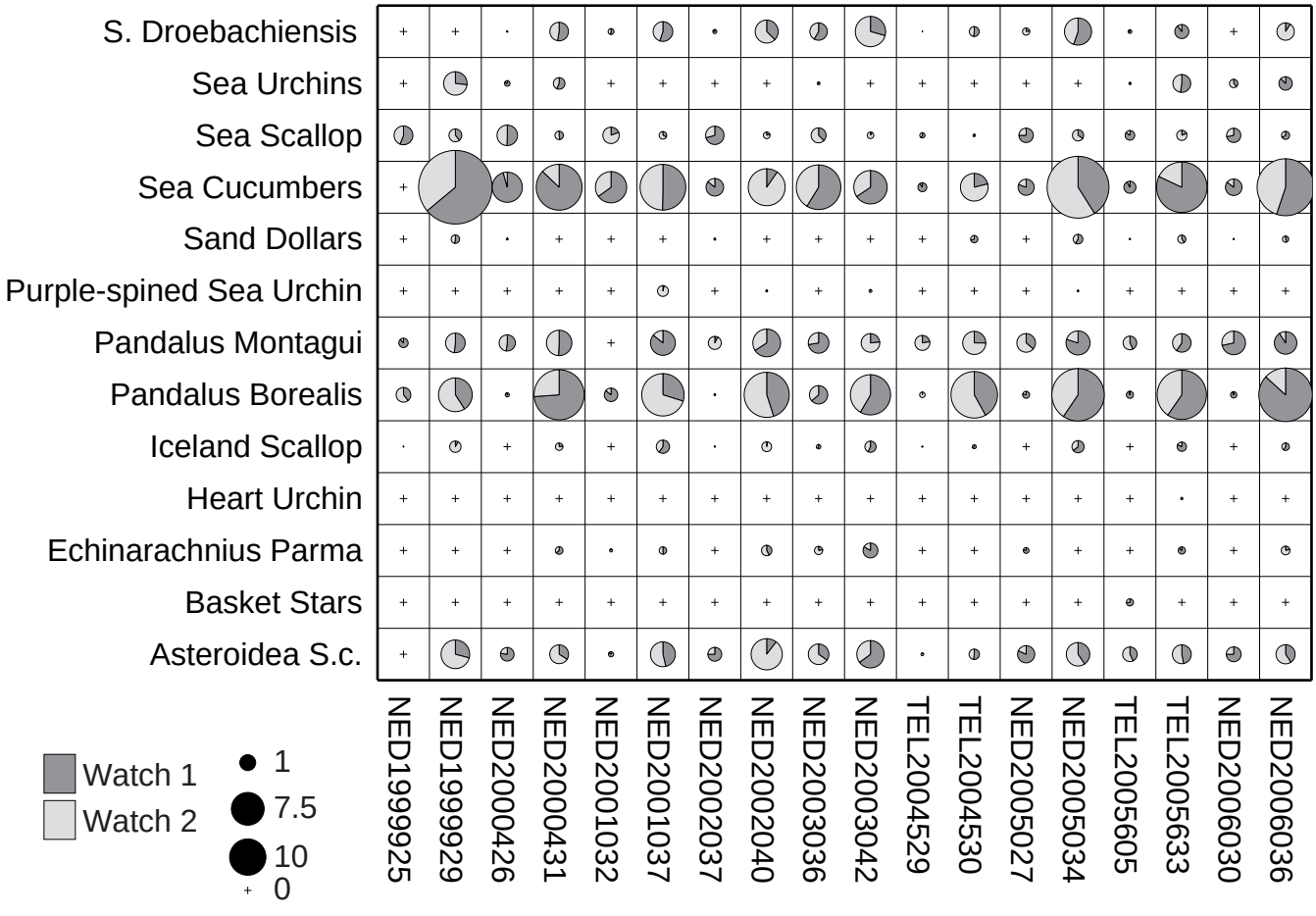

Fig. 77. Weight caught per tow (kg) by Watch from the Summer Ecosystem surveys.

Appendix 1: Metadata associated with the project. Discovery metadata are information which enable the scientific users to discover and access data through various distributed, integrated information technology systems (e.g. the Internet). Associated with this publication, discovery metadata have been created specifically for 'DFO Maritimes Research Vessel Trawl Surveys Invertebrate Observations'. Given below are what will appear on a typical public discovery metadata portal such as the USA National Aeronautics and Space Administration (NASA), Global Change Master Directory (GCMD) discovery portal (http://gcmd.nasa.gov).

Entry Title
DFO Maritimes Research Vessel Trawl Surveys Invertebrate Observations

Entry ID
OBIS.DFOgfsDBinv

Summary
Beginning in 1999 selected invertebrates began to be systematically recorded in Canadian Department of Fisheries and Oceans (DFO) Maritimes Research Vessel Trawl Surveys. This is an OBIS-formatted view of selected invertebrate species from these surveys. Refer to the parent metadata records for more information about the surveys.

PURPOSE: OBIS-formatted data from Canadian Department of Fisheries and Oceans (DFO) Maritimes Research Vessel Trawl Surveys.

OBIS Schema fields implemented in this data set are: InstitutionCode, CatalogNumber, Citation, FieldNumber, collector, YearCollected, MonthCollected, DayCollected, TimeOfDay, startYearCollected, startMonthCollected, startDayCollected, startTimeOfDay, endYearCollected, endMonthCollected, endDayCollected, endTimeOfDay, ContinentOcean, locality, StartLatitude, StartLongitude, EndLatitude, EndLongitude, Latitude, Longitude, MinimumDepth, MaximumDepth, Temperature, samplesize, ScientificName, kingdom, phylum, class, order, family, genus, species, ObservedWeight, ObservedIndividualCount

For OBIS Schema concept details see http://www.iobis.org/tech/provider/

Additional fields that can be provided upon request: gear, geardescription, MINIMUMSIZE, MAXIMUMSIZE, AVERAGESIZE, AVERAGESIZE5CM

Parent DIF
This data set description is a member of a collection. The collection is described in OBIS.DFOgfsDB

Geographic Coverage
N: 47.85 S: 39.97 E: -56.48 W: -69.98

Data Set Citation
Dataset Creator: Tremblay, J. and Branton, B
Dataset Title: DFO Maritimes Research Vessel Trawl Surveys Invertebrates
Dataset Series Name: OBIS Canada Digital Collections
Dataset Release Date: 2007
Dataset Release Place: Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada
Dataset Publisher: OBIS Canada
Version: 1
Data Presentation Form: Digital

Temporal Coverage
Start Date: 1999-07-01

Location Keywords
OCEAN > ATLANTIC OCEAN > NORTH ATLANTIC OCEAN > SCOTIAN SHELF
OCEAN > ATLANTIC OCEAN > NORTH ATLANTIC OCEAN > BAY OF FUNDY
OCEAN > ATLANTIC OCEAN > NORTH ATLANTIC OCEAN > GULF OF MAINE

Appendix 1. Cont'd.

Science Keywords
AGRICULTURE > AGRICULTURAL AQUATIC SCIENCES > FISHERIES
BIOLOGICAL CLASSIFICATION > ANIMALS/INVERTEBRATES
BIOLOGICAL CLASSIFICATION > ANIMALS/INVERTEBRATES > ARTHROPODS
BIOLOGICAL CLASSIFICATION > ANIMALS/INVERTEBRATES > ARTHROPODS > CRUSTACEANS
BIOLOGICAL CLASSIFICATION > ANIMALS/INVERTEBRATES > ARTHROPODS > CRUSTACEANS > DECAPODS
BIOLOGICAL CLASSIFICATION > ANIMALS/INVERTEBRATES > ECHINODERMS
BIOLOGICAL CLASSIFICATION > ANIMALS/INVERTEBRATES > ECHINODERMS > SEA STARS
BIOLOGICAL CLASSIFICATION > ANIMALS/INVERTEBRATES > ECHINODERMS > SEA URCHINS
BIOLOGICAL CLASSIFICATION > ANIMALS/INVERTEBRATES > MOLLUSKS
BIOLOGICAL CLASSIFICATION > ANIMALS/INVERTEBRATES > MOLLUSKS > BIVALVES
BIOSPHERE > ECOLOGICAL DYNAMICS

ISO Topic Category
BIOTA
OCEANS

Platform
SHIPS

Instrument
BOTTOM TRAWL

Project
OBIS >OCEAN BIOGEOGRAPHIC INFORMATION SYSTEM

Quality
Benthic invertebrates were reported inconsistently or not at all from 1970-1998. In 1999 an effort was initiated to regularly capture data on selected invertebrate taxa that are retained in the trawl. These taxa were lobster, several species of crab, scallops, and several groups of echinoderms. These taxa were selected because they occurred regularly in the trawl catch, they could be quantified accurately, and several had existing or potential commercial value.

Access Constraints
None.

Use Constraints
Acknowledge the use of specific records from contributing databases in the form appearing in the 'Citation' field thereof (if any); and acknowledge the use of the OBIS facility.

For information purposes, email to obissupport@marine.rutgers.edu the full citation of any publication made (printed or electronic) that cites OBIS or any constituent part.

Recognize the limitations of data in OBIS.

Data Set Progress
IN WORK

Originating Center
Saint Andrews Biological Station

Data Center
Canada Regional Ocean Biogeographic Information System (OBIS) Node
Data Center URL: http://www.marinebiodiversity.ca/OBISCanada

Data Center Personnel
Name: OBIS CANADA ADMINISTRATION
Phone: (902) 426-1473
Email: bajonal at mar.dfo-mpo.gc.ca
Contact Address:
Bedford Institute of Oceanography
PO Box 1006
City: Dartmouth
Province or State: Nova Scotia
Postal Code: B2Y 4A2
Country: Canada

Appendix 1. Cont'd.

Distribution
Distribution Media: HTTP
Distribution Format: OBIS Schema
Fees: None

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Country: CANADA
View entire list

Related URL
Link: GET DATA

Reference

Tremblay M.J., G.A.P. Black and R.M. Branton. 2007. The distribution of common decapod crustaceans and other invertebrates recorded in annual ecosystem surveys of the Scotian Shelf 1999-2006. Can. Tech. Rep. Fish. Aquat. Sci. 2762: iii + 74 p.

Metadata Name and Version
Metadata Name: CEOS IDN DIF
Metadata Version: VERSION 9.7

Creation and Review Dates
DIF Creation Date: 2007-07-08