A SURVEY OF WEATHERVANE SCALLOPS IN KAMISHAK BAY, ALASKA, 2001

by

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ABSTRACT

During 12-17 May 2001, the Alaska Department of Fish and Game conducted an area-swept survey of the weathervane scallops *Patinopecten caurinus* located in Kamishak Bay, Lower Cook Inlet, Alaska. A total of 38 successful tows, each 1.0 nautical mile (nmi) in length and representing a unique station, were made with the survey dredge. Nine tows were repeated between two stations during the survey as part of a video assessment study. Aggregate weight of material retained by the survey dredge from the 38 unique stations totaled 6,373 kg (14,049 lb), and catch weights of individual tows ranged from 22 to 503 kg (49 to 1,108 lb). Debris, primarily mud and gravel, accounted for 3,679 kg (8,111 lb), or 57.7% of the aggregate survey catch. Aggregate scallop catch among all tows was 2,334 kg (5,146 lb). Scallop catches rates ranged from 0.0 to 212.6 kg/nmi (0.0 to 468.6 lb/nmi). The survey used an adaptive design in which the Kamishak Bay scallop bed was defined to include only stations where catch was equal or greater than 9.1 kg/nmi (20.0 lb/nmi). Mean scallop catch and 95% confidence interval (95% C.I.) for stations within the defined bed was 92.1 ±26.8 kg/nmi (203.0 ±59.1 lb/nmi). Based on an estimation of the scallop bed encompassing 52 nmi^2, the scallop population biomass was 3,637 ±1,058 metric tons (8.0 ±2.3 million lb). A total of 5,517 individual scallops were caught; catch abundance among tows ranged from 0 to 513.9 scallops/nmi. Mean catch abundance and 95% C.I. within the defined bed was 211.9 ±62.1 scallops/nmi, estimated population abundance and 95% C.I. within the defined bed was 8.4 ±2.5 million scallops. Based on estimated population biomass and a mean meat recovery rate of 6.37%, harvesting the population at the maximum regulatory allowance of 20,000 lb was recommended in 2001 as this would result in an instantaneous harvest rate of 3.92%, substantially below estimated natural mortality.

Additional information is provided on estimated scallop growth rates and depth distribution. Survey bycatch, including Tanner crab, king crab, and fish, is also discussed.

INTRODUCTION

The commercial fishery for weathervane scallops *Patinopecten caurinus* in Kamishak Bay, Alaska dates to 1983 when the Alaska Board of Fisheries directed the Alaska Department of Fish and Game (ADF&G) to allow restricted exploratory scallop fishing (Kimker 1994). Fisheries in 1983 and 1984 had limited participation, partly due to the following restrictions:

1. Gear was limited to a 1.8-m (6-ft) wide dredge with a minimum ring size of 10.2 cm (4.0 inch), inside diameter.
2. Only one unit of gear could be deployed at a time.
3. A logbook must be maintained while fishing and submitted after fishing.
4. Vessel operators must check-in with the Homer office before and after each trip.
5. An observer must be taken on the vessel if requested by the department.

These were more restrictive measures than for other scallop fisheries off Alaska (Shirley and Kruse 1995). Based on a 1984 ADF&G survey (Hammarstrom and Merritt 1985) and preliminary fisheries catch data, the Alaska Board of Fisheries in 1985 adopted a guideline harvest range (GHR) of 4.5-9.1 metric tons (mt; 10,000-20,000 lb) of shucked scallop meats and a 15 August to 31 October fishing season.

Annual harvest increased from 1.1 mt (2,346 lb) of shucked meats in 1983 to 7.0 mt (15,364 lb) in 1986, and corresponding catch per unit of effort (CPUE) increased from 9.8-16.4 kg (21.5-36.2 lb) of shucked meats/h (Table 1). However, initial fishing in 1987 yielded an unexpectedly low CPUE of 6.8 kg (15.1 lb) of shucked meats/h, and the fishery was closed with a catch of only 163.3 kg (360 lb) of shucked meats (Kimker 1994). Anecdotal information suggested the Kamishak Bay scallop bed was illegally fished between the 1986 and 1987 seasons (Kimker 1996*b*). Although fishing was allowed during the 1988-1992 seasons, no vessels fished because ADF&G lacked fishery-independent assessments and could not guarantee that the fishery would remain open for more than a single delivery.

In 1993, ADF&G acted to protect dwindling crab resources by setting bycatch limits in the scallop fishery at 0.5% of the estimated populations of king or Tanner crabs. The 1993 harvest yielded 9.1 mt (20,115 lb) of shucked meats, whereas the 1994 harvest yielded 9.3 mt (20,431 lb) of shucked meats (Table 1). In the spring of 1995, the National Marine Fisheries Service closed federal waters off Alaska to scallop fishing following the identification of a regulatory problem. Existing regulations allowed unrestricted fishing by vessels not registered with the state of Alaska (National Marine Fisheries Service, News Release Nos. 95-20, 95-61, and 95-91, Juneau, AK). Because the Kamishak Bay scallop bed is largely located in federal waters, no fishing occurred in 1995 (Kimker 1996*b*). Amended federal regulations allowed commercial fishing to resume in 1996.

Weathervane scallops in Kamishak Bay were initially surveyed in 1984 (Hammarstrom and Merritt 1985). Fishery catch rates increased between 1983 and 1996, and catch rates in 1993 and 1994 were some of the highest since the fishery began (Table 1). Because the fishery was closed

in 1995 following seasons of high catch rates in 1993 and 1994, the scallop fleet requested the harvest allowance be raised for 1996. However, observed CPUE increases in recent years may have been a function of increased fishing power rather than increased scallop abundance. Due to changes in fishing technology, considering CPUE changes from 1984 to present as an accurate index of population abundance may have overestimated the true population in recent years.

Based on changes in fishery performance, coupled with the absence of recent stock abundance data for Kamishak Bay scallops, a fishery-independent survey was needed. ADF&G, with industry support, reinitiated a scallop survey of the Kamishak Bay scallop bed in 1996 (Bechtol and Gustafson 2000). Intending to conduct a biennial survey, a follow-up survey in 1998 was only marginally successful due to loss of the primary survey dredge. Therefore, another survey with a new dredge was conducted in 1999, and this survey has since been conducted biennially (Trowbridge and Bechtol 2003). This report documents methods used to conduct the 2001 weathervane scallop survey in the Kamishak Bay District and the recommendations for the subsequent commercial fishery harvest levels.

Survey Objectives

1. Determine the abundance, age, size, and sexual maturity of weathervane scallops caught by a 2.4-m (8-ft) dredge with 10.2-cm (4-in) inside diameter rings and a 3.8-cm (1.5-in) liner.
2. Estimate scallop meat recovery.
3. Determine the relative bycatch of king and Tanner crabs and other non-scallop species.
4. Calculate a GHR based on the current estimated population size, and evaluate changes in scallop distribution and density since previous surveys.
5. Estimate scallop catchability in the 2.4-m (8-ft) dredge using a video camera.

Study Area

Although weathervane scallops are found throughout the Kamishak Bay District, the fished component of the population is aggregated in a limited area, or scallop bed, located east of Augustine Island (Figure 1). This study, as well as previous surveys, focused on this aggregation (Hammarstrom and Merritt 1985; Bechtol and Gustafson 2000, 2002). The scallop bed occurs on relatively flat or gradually sloping bottom ranging from 30 to 90 m (20 to 50 fathoms) in depth with mud or sand substrate interspersed with shale outcroppings.

METHODS

Vessel and Gear

The state research vessel *Pandalus* conducted the 2001 Kamishak Bay survey. The *Pandalus* has an overall length of 20.2 m (66 ft), a displacement of 100 mt, and a 365 hp diesel main engine.

Survey staff included 3 biologists and 3 vessel crewmembers. Vessel tow speed was approximately 7,420 m/h (4.0 nautical miles per hour; 4.0 nmi/h), with a tow duration of approximately 15 min, and an average cable scope (ratio of tow cable to bottom depth) of about 4.4:1. Dredge setting, tow, and retrieval occurred from about 0800 hours to 1700 hours each day.

Although a consistent dredge design has been used for all Kamishak Bay scallop surveys, a heavier dredge has generally been used since the 1984 survey (Bechtol and Gustafson 2002). The dredge is 2.4-m (8-ft) in width and the retainer bag was fitted with a 3.8-cm (1.5-in) mesh liner to facilitate retention of small scallops.

Weathervane scallop catchability in the dredge was assumed equal to 1.0 such that all scallops larger than the liner stretch mesh were retained (Hammarstrom and Merritt 1985; Bechtol 2000; Bechtol and Gustafson 2000, 2002). An age-structured model for the Kamishak Bay scallop stock treated gear selectivity as a logistic function with selectivity increasing with scallop age to an asymptotic value of approximately 1.0 for scallop sizes that are selected by the commercial fishery (Bechtol 2000). However, this model estimate is likely biased low because of the strong influence that the biomass estimate from the dredge survey has in tuning the model performance. In fact, recent video sled analysis suggested that catchability might be substantially less than 1.0 (Gregg Rosenkranz, ADF&G, Kodiak, personal communication). Thus, biomass estimates from the dredge survey are likely conservative, but by an unknown amount. Nonetheless, the ADF&G survey gear is considered adequate and sufficiently consistent to allow estimation of biomass and abundance of the underlying population in order to provide for sustainable yield.

Study Design

Sample Area

The preliminary sample area for the 2001 survey was based on results of previous surveys. The 1984 survey encompassed a 56-nmi^2 (1.0 nmi = 1,855 m = 6,076 ft) study area, divided into 1-nmi^2 grids, and sampled a total of 47 stations (Hammarstrom and Merritt 1985). Based on scallop catches during department trawl surveys for king and Tanner crabs, we now believe the Kamishak Bay scallop bed covers a larger area than was sampled in 1984 (Kimker 1996*a*; Bechtol 2001). The 1996 survey involved 26 tows that encompassed a 52-nmi^2 study area (Bechtol and Gustafson 2000). Due to the loss of the survey dredge during the 1998 survey, a follow-up survey was conducted in 1999; the 1999 survey resulted in 45 successful tows and a defined bed of 58-nmi^2 (Bechtol and Gustafson 2002).

Survey Design

To allow greater survey coverage and identification of the scallop distribution, an adaptive, systematic survey design has been used since 1996. Sample stations were defined by overlaying a grid of 1.0-nmi squares over the study areas (Figure 2). A systematic design with two primary units was used in which alternate stations were identified for potential sampling. The primary sample unit was randomly selected, so there was equal probability of selecting either unit. The vessel

skipper, in cooperation with the project leader, determined the specific tow location within each sample station. The dredge was towed for a distance of approximately 1.0 nmi in the direction of the prevailing current within the sample station. Under the adaptive design, adjacent stations were added if the tow catch in a station exceeded 9.1 kg (20 lb) of whole scallops, which was approximately 5% of the highest station catch observed during the 1996 survey (Bechtol and Gustafson 2000). Thus, the 9.1-kg catch level was used to define the bed margin within a sampling unit. The systematic pattern of sampling alternate survey stations was preserved when expanding survey area margins.

For animal populations with individuals that are randomly distributed, a single systematic sample provides good variance estimates. Because weathervane scallops have a patchy distribution and are not uniformly clustered within beds, a systematic sample tends to overestimate the population variance (Thompson 1987). However, we decided to forego precision about the variance estimate in order to equally distribute sampling effort across the survey area and better define the weathervane scallop bed boundary.

Data Collection

During each tow, the vessel captain recorded the following:

1. sequential tow identification number;
2. alphanumeric station code;
3. date;
4. tow start and stop location (latitude and longitude);
5. true tow course heading;
6. vessel speed;
7. tow start and stop time;
8. distance towed;
9. maximum and minimum depth;
10. sea conditions;
11. amount of cable deployed (scope); and
12. gear performance.

Upon completion of each tow, the catch was washed clean of mud and then separated into weathervane scallops, weathervane scallop shells, fish, crab, and other bycatch, including debris. Commercially important crab species were examined to determine carapace width, shell age, and sex, then discarded. Fish were weighed, enumerated by major species group, and discarded. Debris, assorted invertebrates, and any remaining bycatch were weighed and their relative contribution visually estimated (e.g., 60% starfish and 40% rocks).

Weathervane Scallop Sampling

Total live weight and numbers of weathervane scallops, including broken shells with attached viscera, were recorded. Weathervane scallop shells and shell fragments without attached viscera were weighed and discarded. Empty weathervane scallop shells with both valves connected by

an intact ligament (referred to as cluckers), were cleaned, measured (shell height), aged, labeled, and retained for archival.

Twenty randomly selected weathervane scallops from each tow were weighed and shucked aboard the vessel. Their meats were placed into a container, and their dorsal shells were cleaned, labeled, measured, aged, and placed in storage for later age verification. A sample size of at least 600 scallops was desired to achieve a predetermined precision in the estimated age class proportions (Thompson 1987). Non-random samples of immature weathervane scallops from each tow were also shucked, cleaned, measured, aged, and stored for representative age verification. When possible, shell heights of all weathervane scallops remaining from a tow were captured with an electronic measuring board to construct height frequency distributions.

Fresh weathervane scallop meat recovery was estimated each day from whole weight of the approximately twenty scallops sampled from each tow and the weight of their shucked meats. Mean fresh meat recovery was estimated as pooled meat weight divided by pooled whole weathervane scallop weight.

Random samples of approximately 10% of the aged scallops were re-aged by two readers to examine between-reader and within-reader variance. Although data are not reported here, there was good agreement both within and between readers.

Data Analysis

Weathervane scallop age and size composition data were pooled within each tow. Age and size data, weighted by within-tow sample size, were pooled among all successful tows to estimate population age and size compositions. Shell height-at-age, L_t was modeled with the following von Bertalanffy growth equations (Ricker 1975):

$$L_t = L_\infty (1 - e^{-K(t-t_0)}) \tag{1}$$

where

K_l is the constant relative rate of growth in length,
t is age (time) in years,
t_0 is the age of theoretical zero length, and
L_∞ is the theoretical mean maximum length.

The Microsoft Excel Solver utility was used to minimize sums of squares while adjusting the constant growth rate, t_0, and theoretical mean maximum size in the above equation. For subsequent analysis of height composition, shell heights were rounded to the nearest 10 mm.

The weathervane scallop population estimate derived from the Kamishak Bay surveys was based on area-swept calculations (Sokal and Rolf 1969; Gunderson 1993), similar to estimates for previous weathervane scallop surveys in southcentral Alaska (Hammarstrom and Merritt 1985;

Bechtol and Gustafson 2000, 2002). Mean catch per nautical mile ($\bar{c}$) and it's variance (s^2) were calculated by

$$\bar{c} = \frac{\sum_{i=1}^{n} \frac{c_i}{d_i}}{n} \quad , \tag{2}$$

and

$$s^2 = \frac{1}{n-1} \sum_{i=1}^{n} \left(\frac{c_i}{d_i} - \bar{c} \right) \quad , \tag{3}$$

where

c_i is the catch of a species, either as abundance or weight, in sample tow i,
d_i is the distance towed in nautical miles for sample tow i, and
n is the number of stations sampled.

An estimate of the population (P) was calculated by expanding $\bar{c}$ over the surveyed area as

$$P = \left(\frac{6{,}076}{8} \right) N\bar{c} \quad , \tag{4}$$

where

6,076 is the length in feet of a nautical mile,
8 is the width of the dredge in feet, and
N is number of possible survey stations within the survey area.

Variance of the surveyed population was estimated by

$$Var(P) = N^2 \left(\frac{N-n}{N} \right) \left(\frac{6{,}076}{8} \right)^2 \frac{s^2}{n} \quad , \tag{5}$$

For these estimates, calculations for weathervane scallops were applied to the scallop bed as defined by the adaptive survey design. For other species, calculations were based on the surveyed area, including all survey tows, in order to use more of the available data. Calculations maintained a balanced survey design such that the total number of possible survey stations was twice the number of stations actually sampled; i.e., each sampled station was matched to an unsampled station with one exception.

The confidence interval was constructed as

$$P \pm t_{(0.975;n-1)} \sqrt{Var(P)} \quad , \tag{6}$$

Age Composition

To extrapolate the observed subsample age composition to the total population, and to account for potential bias in selection of aged scallops, an age-at-size matrix was developed using data from the aged scallops. Shell heights smaller than 35 mm were assumed to be age-1 scallops based on the height of the first annulus observed in older scallops. For larger scallops, shell age was either: (1) the estimated age based on visually observed growth patterns; or (2) the assigned age based on the scallop size composition observed in a given 10-mm or 15-mm size stratum of the age-at-size matrix.

2001 SURVEY RESULTS

A total of 38 successful tows, each 1.0 nmi in length and each representing a unique survey station, were made during the 12-17 May 2001 survey of weathervane scallops in Kamishak Bay (Table 2, Figure 2). An additional 9 replicate tows, averaging 0.7 nmi in length, were distributed over two stations as part of a towed video sled study; results of the video sled study will be reported elsewhere (Gregg Rosenkranz, ADF&G, Kodiak, personal communication).

For the 38 successful tows, excluding replicates, the aggregate weight of material retained by the survey dredge totaled 6,372.6 kg (14,049.2 lb; Table 3). Standardized catch weights of individual tows ranged from 22.2 to 502.7 kg/nmi (49.0 to 1,108.3 lb/nmi). Debris, primarily mud and gravel, accounted for 3,678.7 kg (8,110.5 lb), or 57.7% of the aggregate survey catch, although debris contribution to individual tows ranged from 8.3 to 100.0%. The surveyed water depths ranged from 35 to 62 m (19 to 34 fathom; Table 2).

Weathervane Scallops

Scallop Catches

Weathervane scallops were caught in 97.3% (n=37 tows) of the survey tows (Table 3). Aggregate scallop catch among all tows was 2,334.1 kg (5,145.7 lb), or 36.6% of the weight of all material retained by the dredge. Standardized catches of live scallops per 1.0-nmi tow ranged from 0 to 212.6 kg (0 to 468.6 lb). Scallop catch dropped dramatically at the edge of the bed (Figure 3). The largest catches occurred at depths of 46-55 m (25-30 fathom; Figure 4), with the greatest scallop catch weight occurred in tow 01130 (station F07). A total of 5,517 individual scallops, standardized to 5,400 scallops/nmi, were caught during the 2001 survey (Table 4). Catch abundance ranged from 0.0 to 513.9 scallops/nmi with a mean catch of 142.1 scallops/nmi. Greatest scallop catch abundance occurred in tow 01125 (station F05), which yielded 8.9% of total scallop catch weight and 9.5% of total survey scallop abundance.

Scallop shells contributed 56.8 kg (125.3 lb) to total survey catch. The survey dredge retained scallop shells from 58% (n=22) of the stations (Table 3).

Size, Age, and Growth

A total of 5,516 shell heights were measured. Heights ranged from 31 to 201 mm (1.2 to 7.9 in). After standardizing scallop abundance for survey tow length, the effective number of shell heights was 5,402 (Figure 5; Table 5). The most abundant size class was the 160-mm (6.3 in) size class, representing 28.7% of the sampled population. Shell heights were well represented in the 130 to 180 mm (5.1 to 7.1 in) size classes, comprising 88.1 % of the total population.

A total of 609 scallop shells was aged. Scallops ages ranged from age 1 to age 20 (Table 6). Size-at-age from the 2001 survey indicated asymptotic growth for the Kamishak Bay scallop population (Figure 6). The greatest annual growth in height occurred during the first five years of life. Predicted annual growth in height decreased to less than 10% per year after about age 11. Use of an age-at-size matrix resulted in 5,517 ages, adjusted to an effective sample size of 5,403 ages after standardizing for tow length. Age composition data indicated 50% of the surveyed population abundance was younger than age 7.7. Age 6 was the most abundant cohort (20.9% of the estimated population), and ages 6-9 comprised over 50% of the population (Figure 5).

Meat Recovery and Sexual Maturity

Aggregate whole weight of scallops selected randomly for meat recovery was 269 kg (593 lb), and aggregate meat weight was 17.1 kg (37.8 lb) for six sampled survey days (Table 7). Mean meat recovery, weighted by whole daily sample weight, was 6.37%.

Of the 587 weathervane scallops for which sex and spawning status were visually examined, 294 (50%) were classified as male, 282 (48%) as females, and 11 (2%) could not be classified (Table 8). From the pool of 576 scallops for which sex was determined, 99% of the males and 98% of the females were in spawning condition.

Weathervane Scallop Population Estimate

Due to insufficient data to calculate dredge catchability from video observations, the estimate of the weathervane scallop population was based on an assumption of catchability equal to 1.0. Population estimation also applied a balanced survey design such that the number of sampled stations represented one half of the available stations. Because station D03 within the sample unit of the defined bed was not sampled due to the presence of rock structure and a likelihood of gear loss or damage, mean catch within the defined bed was applied to this station. Based on the sampled stations and one unsampled station within the core survey area, the 2001 survey defined the Kamishak Bay District scallop bed as encompassing 52 nmi^2. Mean catch rate and 95% confidence interval for unique stations in 2001 was 92.1 ±26.8 kg/nmi (203.0 ± 59.1 lb/nmi). Multiplying the bed area by mean scallop catch rate and converting the linear tow distance to an area swept calculation yielded a weathervane scallop population biomass estimate and 95% confidence interval of 3,637 ±1,058 metric tons (8.0 ±2.3 million lb). Based on a mean scallop catch abundance of 211.9 ±62.1 (95% C.I.) scallops/tow, estimated population abundance was 8.4 ±2.5 (95% C.I.) million scallops within the defined bed.

Recommended Weathervane Scallop Harvest Guideline

Assuming a mean meat recovery rate of 6.37%, the estimated population biomass of 3,637 mt (8.0 million lb) equates to 231,529 kg (510,428 lb) of scallop meats. Harvesting the population at the maximum regulatory allowance of 9,072 kg (20,000 lb) of meats would result in an instantaneous harvest rate of 3.92%. This harvest rate is well below the instantaneous natural mortality of 14% estimated by a previous age-structured model for the Kamishak population (Bechtol 2000) and should readily provide for sustained yield. Therefore, the maximum harvest level of 20,000 lb of meats was recommended for the 2001 weathervane scallop fishery.

Tanner Crab

A standardized total of 7,864.3 Tanner crab, with an aggregate weight of 201.9 kg (445.1 lb), was caught in 36 stations (95%) in the 2001 Kamishak Bay survey (Tables 3 and 4). Tanner crab catch rates ranged from 0.0 to 32.7 kg/nmi (0.0 to72.0 lb/nmi) and 0.0 to 915.0 crab/nmi, with the greatest catch from tow 01115 in station E08 (Figure 7). Catches occurred across a wide depth range, although greatest catches were in depths of 53 to 55 m (29 to 30 fathom; Figure 4).

King Crab

A standardized total of 13.8 king crab, with an aggregate weight of 34.2 kg (75.4 lb), was caught by the survey (Tables 3 and 4). King crab were caught in 32% (n=12) of the survey stations. Tows 01103 (station G04) and 01107 (station C10) yielded the greatest king crab abundance (n=2.0/nmi; Figure 8). Catches of king crab occurred across a wide depth range, although greatest catches were in depths of 53 to 59 m (29 to 32 fathom; Figure 4).

Miscellaneous Fish

Fish species were caught in all (n=38) survey tows. Catch biomass of fish ranged from 0.1 to 7.2 kg/nmi (0.2 to 15.8 lb/nmi) with the greatest catch, 7.2 kg (15.8 lb), or 1.1% of the total survey fish catch, from tow 01128 (station F01; Table 3; Figure 9). Standardized catch abundance ranged from 1.0 to 34.7 fish/nmi (Table 4). Butter sole *Isopsetta isolepis* was the most abundant species caught, comprising 50.7% of all fish catches and yielding a mean catch of 7.3 fish/nmi among all tows (Table 9). Catches of fish as a species group occurred across a wide depth range (Figure 4).

DISCUSSION

A total of 38 tows were made in the 2001 survey for weathervane scallops in the Kamishak Bay District; 25 tows were within the defined bed, described as tows where standardized scallop

catch was equal or greater than 20 lb/nmi (9.1 kg/nmi). Under an assumption that survey dredge catchability equals 1.0, the point estimate and 95% confidence interval for weathervane scallops in was 3,637 ±1,058 metric tons (8.0 ±2.3 million lb) within the defined bed in 2001. Estimated population abundance was 8.4 ±2.5 (95% C.I.) million scallops. Relative to the previous comprehensive dredge survey in 1999, the area of the defined bed decreased by approximately 10% from 58 nmi^2 to 52 nmi^2 (Table 10). In addition, survey CPUE, defined as whole scallop weight (kg/nmi), declined approximately 8%, resulting in a 14% decline in estimated population biomass and a 5% decline in estimated population abundance.

We do not understand the processes affecting recruitment, or how various aggregations within the surveyed bed contribute to the reproductive success of the weathervane scallop population in Kamishak Bay. More than half of the Kamishak Bay population was age 8 or younger in the 2001 survey, indicating environmental conditions have been sufficient for stable reproduction and recruitment in recent years (Figure 5). The time series of age composition data also appears to exhibit continued and steady growth and recruitment for this scallop bed (Figure 10). Notable is the progression of a strong 1993-year class from age-3 scallops in 1996 to age-8 scallops in 2001 (Figure 10). Commercial fishery age data suggest mortality increased rapidly around age 13, as evidenced by declines in cohort abundance after this age. In addition, scallops younger than age 6 tend to be more prominent in the surveys than in the commercial fisheries, probably due to the use of a liner to retain smaller scallops in the survey gear (Figures 5 and 10).

An aspect of weathervane scallop management is to minimize the bycatch of nontarget species, particularly Tanner and king crabs. Populations of these crab species are insufficient to support fisheries in the Kamishak Bay District (Bechtol et al. 2002). However, dredge catches of Tanner crab, particularly juveniles, during the scallop survey may someday be used to improve crab assessment by providing data to supplement ADF&G bottom trawl survey information. The scallop dredge appears to catch a greater abundance of smaller Tanner crab cohorts than is observed in ADF&G trawl surveys to assess crab (unpublished data), and the trawl survey has long been recognized as having low selectivity for Tanner crab smaller than 92 mm carapace width (Kimker 1996*a*; Bechtol 2001; Bechtol and Gustafson 2002). Although the red king crab population remains well below historical levels, catches by the scallop dredge survey may prove to be a useful index of red king crab abundance and distribution (Table 4). The scallop fishery typically avoids areas of significant crab aggregations because of bycatch restrictions that could potentially curtail the fishery (Trowbridge and Bechtol 2003). The largest catch rates for weathervane scallops tended to occur in depths of 46-57 m (25-31 fathoms; Figure 4). Although the depth distributions of Tanner crab and red king crab overlap that of weathervane scallops, the geographic distributions of these species show less overlap (Figures 3, 7, and 8).

The maximum scallop age of 20 years observed in the 2001 survey was slightly less than the age 24 maximum observed in the 1996 and 1999 surveys. Under the empirical approach of Hoenig (1983), natural mortality rates for the Kamishak Bay population can be approximated as M=0.19, corresponding to an annual mortality rate of 17%, for a maximum observed age of 24 years. This agrees well with estimates of 4-22% obtained by Kruse (1994) for *P. caurinus* and the median estimate of 15% reported by Kruse (1994) using a maximum scallop age of 28 years as reported by Hennick (1973). Preliminary efforts at a structured model for the Kamishak Bay scallop stock

suggested that instantaneous fishing mortality has historically been less than 5% (Bechtol 2000). Although fishing effort has not occurred every year since the fishery's inception in 1983 (Trowbridge and Bechtol 2003), the fishery appears to have been sustained under this constant harvest strategy.

This weathervane scallop harvest in Kamishak Bay occurs entirely with commercial dredges; scallop catches by recreational harvesters or other commercial other gears are negligible (Trowbridge et al. 2000). Because the Kamishak Bay scallop bed is surveyed biennially, a harvest determination based on the 2001 survey will apply to commercial fisheries in 2001 and 2002. Management for the regulatory maximum allowable harvest of 20,000 lb of scallop meats will represent a harvest rate of 3.92% of the 2001 standing stock. Under an approach that fishing mortality should not exceed natural mortality, management in 2001 and 2002 for the maximum regulatory allowable harvest in Kamishak Bay should present a conservative approach to the scallop fishery.

LITERATURE CITED

Bechtol, W.R. 2000. Preliminary evaluation of multiple data sources in an age-structured model for weathervane scallops in Kamishak Bay, Alaska. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A00-03, Anchorage.

Bechtol, W.R. 2001. A bottom trawl survey for crabs and groundfish in the Southern, Kamishak, and Barren Islands Districts of the Cook Inlet Management Area, 19-23 July and 16-23 August 1999. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A01-05, Anchorage.

Bechtol, W.R., and R. Gustafson. 2000. Abundance and biomass of weathervane scallops in Kamishak Bay, Alaska, 1996. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A99-14, Anchorage.

Bechtol, W.R., and R.L. Gustafson. 2002. A survey of weathervane scallops in Kamishak Bay, Alaska, 1998 and 1999. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A02-21, Anchorage.

Bechtol, W.R., Trowbridge, C., and N. Szarzi. 2002. Tanner and king crabs in the Cook Inlet Management Area: stock status and harvest strategies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A02-07, Anchorage.

Gunderson, D.R. 1993. Surveys of fish resources. John Wiley & Sons, Inc., New York. 248 p.

Hammarstrom, L.F., and M.F. Merritt. 1985. A survey of Pacific weathervane scallops (*Pecten caurinus*) in Kamishak Bay, Alaska. Alaska Department of Fish and Game, Informational Leaflet No. 252, Juneau.

Hennick, D.P. 1973. Sea scallop *Patinopecten caurinus* investigations in Alaska. Alaska Department of Fish and Game, Division of Commercial Fisheries, Completion Report 5-23-R, Juneau.

Hoenig, J.M. 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 83:898-903.

Kimker, A 1994. Cook Inlet Area Annual Shellfish Management report. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 2A94-01, Anchorage.

Kimker, A 1996*a*. A bottom trawl survey for crabs in the Southern, Kamishak, and Barren Islands Districts of the Cook Inlet Management Area, June 18-July 10, 1995. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Regional Information Report No. 2A96-24, Anchorage.

LITERATURE CITED (Continued)

Kimker, A 1996*b*. Cook Inlet Area: annual shellfish management report, 1995-1996. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 2A96-30, Anchorage.

Kruse, G.H. 1994. Fishery management plan for commercial scallop fisheries in Alaska. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Draft Special Publication 5, Juneau.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Journal of Fisheries Research Board of Canada, Bulletin 191.

Shirley, S.M., and G.H. Kruse. 1995. Development of the fishery for weathervane scallops *Patinopecten caurinus* (Gould 1850) in Alaska. Journal of Shellfish Research 14:71-78.

Sokal, R.R., and F.J. Rohlf. 1969. Biometry. W.H. Freeman and Company, San Francisco.

Thompson, S.K. 1987. Sample sizes for multinomial proportions. American Statistician 41:42-46.

Trowbridge, C., N. Szarzi, and W.R. Bechtol. 2000. Review of commercial, sport, and personal use fisheries for miscellaneous shellfish in Lower Cook Inlet: Report to the Alaska Board of Fisheries. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A00-13, Anchorage.

Trowbridge, C.E., and W.R. Bechtol. 2003. Review of commercial fisheries for Dungeness crab, shrimp, and miscellaneous shellfish in Lower Cook Inlet: Report to the Alaska Board of Fisheries. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A03-09, Anchorage.

Table 1. Weathervane scallop harvests from the Kamishak Bay District, Cook Inlet Management Area, 1983-2001.

Year	Number of vessels	Catch (lb) of shucked meats	CPUE (lb/hour)
1983	1	2,346	21.5
1984	3	6,3.05	25.4
1985[a/]	1	11,810	39.5
1986	3	15,364	36.2
1987 [b/]	2	360	15.1
1988	0	No Effort	
1989	0	No Effort	
1990	0	No Effort	
1991	0	No Effort	
1992	0	No Effort	
1993	3	20,115	38.1
1994	4	20,431	44.6
1995[c]	0	No Effort	
1996	5	28,228	52.9
1997	3	20,336	50.9
1998	1	Confidential	
1999	3	20,315	60.8
2000	3	20,516	74.6
2001	2	Confidential	

[a/] Season and harvest guideline set by regulation.
[b/] Season closed by E.O. on August 21, 1987, one week after opening , due to low CPUE.
[c/] Only state waters opened.

Table 2. Vessel log of dredge tows made during a weathervane scallop survey in the Kamishak Bay District, 2001.

Tow number	Station	Date	Tow start		Course (°True)	Speed (nautical miles/h)	Duration (minutes)	Distance (nautical miles)	Tow depth (fathoms)		Scope (fathoms)
			Latitude (°N)	Longitude (°W)					Minimum	Maximum	
01101	E6	May 12	59.3620	153.0970	062	3.90	17	1.11	26	27	115
01102	G2	May 12	59.4258	153.0102	352	4.00	15	1.00	24	25	110
01103	G4	May 12	59.3923	153.0423	069	4.04	15	1.01	26	26	125
01104	E2	May 12	59.4280	153.0780	339	4.08	15	1.02	22	23	110
01105	A2	May 12	59.4397	153.2415	152	4.00	15	1.00	19	21	80
01106	C6	May 12	59.3727	153.1727	151	4.00	15	1.00	24	26	125
01107	C10	May 13	59.2932	153.1743	064	4.08	15	1.02	29	29	125
01108	C2	May 13	59.4278	153.1705	065	4.00	15	1.01	22	22	110
01109	E4	May 13	59.3927	153.1077	062	4.00	15	1.01	24	25	125
01110	C4	May 13	59.3927	153.1737	062	4.00	15	1.01	23	23	125
01111	G6	May 13	59.3595	153.0403	062	4.00	15	1.00	28	28	125
01112	C8	May 13	59.3278	153.1692	066	4.10	15	1.03	27	27	125
01113	E10	May 14	59.2948	153.1030	062	4.03	15	1.04	31	31	140
01114	G10	May 14	59.2928	153.0405	062	4.00	15	1.00	26	31	140
01115	E8	May 14	59.3282	153.1040	062	4.00	15	1.00	29	29	125
01116	G8	May 14	59.3265	153.0120	334	4.00	15	1.01	30	32	125
01117	H3	May 14	59.4107	152.9792	338	4.00	15	1.00	26	27	115
01118	F3	May 14	59.4093	153.0440	342	4.00	16	1.07	25	26	100
01119	B3	May 14	59.4113	153.1807	334	4.00	15	1.00	21	22	100
01120	B7	May 14	59.3550	153.2073	157	4.00	15	1.01	25	28	100
01121	B11	May 15	59.2895	153.2053	155	4.08	15	1.02	29	30	125
01122	D9	May 15	59.3232	153.1357	159	4.00	15	1.00	30	30	125
01123	D7	May 15	59.3440	153.1117	336	4.04	15	1.01	27	28	125
01124	D5	May 15	59.3750	153.1093	338	4.04	15	1.01	24	26	100
01125	F5	May 15	59.3770	153.0470	345	4.04	15	1.01	26	27	125

Table 2. (page 2 of 2)

Tow number	Station	Date	Tow start Latitude (°N)	Tow start Longitude (°W)	Course (°True)	Speed (nautical miles/h)	Duration (minutes)	Distance (nautical miles)	Tow depth (fathoms) Minimum	Tow depth (fathoms) Maximum	Scope (fathoms)
01126	H5	May 15	59.3783	152.9802	341	4.08	15	1.02	28	30	125
01127	B5	May 15	59.3772	153.2002	074	4.08	15	1.02	25	25	100
01128	F1	May 16	59.4572	153.0707	165	4.04	15	1.01	23	25	100
01129	H7	May 16	59.3542	153.0045	158	4.00	15	1.00	32	33	125
01130	F07	May 16	59.3552	153.0697	160	4.08	15	1.02	29	30	125
01131	H9	May 16	59.3120	152.9830	334	3.96	15	0.99	32	34	140
01132	F9	May 16	59.3123	153.0497	339	4.00	15	1.00	30	31	125
01133	A4	May 16	59.3935	153.2113	346	4.00	15	1.00	22	24	100
01134	B9	May 17	59.3108	153.1780	342	4.08	15	1.02	28	28	125
01135	F11	May 17	59.2902	153.0727	133	4.00	15	1.00	28	28	125
01136	D11	May 17	59.2897	153.1380	140	4.00	15	1.00	32	33	125
01137	A10	May 17	59.3017	153.2325	151	4.02	14	0.94	28	29	125
01138	E12	May 17	59.2608	153.0808	337	4.04	15	1.01	33	33	140
01139	D8	May 17	59.3263	153.1173	045	3.96	10	0.66	28	29	125
01140	D8	May 17	59.3272	153.1165	040	3.96	10	0.66	28	29	125
01141	D8	May 17	59.3272	153.1127	042	3.96	10	0.66	28	29	125
01142	D8	May 17	59.3287	153.1407	042	3.96	10	0.66	27	28	125
01143	D8	May 17	59.3293	153.1397	042	3.96	10	0.66	27	28	125
01144	D8	May 17	59.3308	153.1380	042	3.96	10	0.66	27	28	125
01145	D10	May 18	59.3062	153.1348	156	4.07	12	0.78	30	32	125
01146	D10	May 18	59.3035	153.1313	157	4.07	12	0.78	31	32	125
01147	D10	May 18	59.3048	153.1335	157	4.07	12	0.78	31	32	125
n = 47		n = 7 days							19	34	

Table 3. Catch weight during the 2001 Kamishak Bay District scallop survey.

Tow number	Station	Pounds per nautical mile: Whole scallops	Scallop shells	Tanner crabs	King crabs	Fishes	Debris/ Other	Total catch
01101	E06	329.7	5.4	9.0	0.0	7.2	52.3	403.6
01102	G02	26.0	0.0	2.0	8.0	4.0	182.0	222.0
01103	G04	320.8	23.8	3.0	2.5	2.0	89.1	441.1
01104	E02	125.5	2.0	25.5	0.0	3.9	176.5	333.3
01105	A02	10.0	0.0	6.0	0.0	2.0	400.0	418.0
01106	C06	68.0	0.0	20.0	4.0	4.0	350.0	446.0
01107	C10	176.5	3.9	2.0	13.7	5.9	60.8	262.7
01108	C02	4.0	2.0	7.4	0.0	9.9	186.1	209.4
01109	E04	306.9	9.9	17.8	4.0	9.9	108.9	457.4
01110	C04	31.7	2.0	7.9	4.0	4.0	182.2	231.7
01111	G06	364.0	0.0	3.0	2.0	4.0	54.0	427.0
01112	C08	261.2	9.7	23.3	0.0	7.8	77.7	379.6
01113	E10	15.4	0.0	0.5	0.0	0.5	140.4	156.7
01114	G10	0.0	0.0	0.0	0.0	0.3	1,108.0	1,108.3
01115	E08	248.0	8.0	72.0	0.0	0.5	50.0	378.5
01116	G08	29.7	0.0	0.2	4.0	2.0	41.6	77.5
01117	H03	32.0	0.0	0.5	0.0	2.0	88.0	122.5
01118	F03	319.6	2.8	0.5	3.7	0.2	59.8	386.6
01119	B03	44.0	2.0	4.0	0.0	6.0	458.0	514.0
01120	B07	7.9	0.0	2.0	0.0	7.9	411.9	429.7
01121	B11	2.0	0.5	3.9	9.8	2.0	200.0	218.1
01122	D09	164.0	2.0	58.0	0.0	8.0	48.0	280.0
01123	D07	384.2	5.9	45.5	0.0	1.0	39.6	476.2
01124	D05	301.0	5.9	35.6	0.0	2.0	103.0	447.5
01125	F05	457.4	11.9	5.9	0.0	4.0	61.4	540.6
01126	H05	21.6	0.0	1.0	0.0	1.0	25.5	49.0
01127	B05	64.7	3.9	19.6	0.0	2.0	388.2	478.4
01128	F01	9.9	0.0	1.5	0.0	15.8	281.2	308.4
01129	H07	12.0	0.0	0.1	10.0	1.0	50.0	73.1
01130	F07	468.6	13.7	15.7	3.9	1.0	68.6	571.6
01131	H09	2.0	0.0	0.3	0.0	0.5	131.3	134.1
01132	F09	158.0	1.0	22.0	0.0	1.0	56.0	238.0
01133	A04	4.0	2.0	16.0	0.0	4.0	516.0	542.0
01134	B09	154.9	2.9	7.8	5.9	3.9	198.0	373.5
01135	F11	0.0	0.0	0.0	0.0	1.0	890.0	891.0
01136	D11	218.0	4.0	1.0	0.0	10.0	30.0	263.0
01137	A10	2.1	0.0	4.3	0.0	1.1	485.1	492.6
01138	E12	0.5	0.0	0.2	0.0	4.2	261.4	266.3
Total	n = 38	5,145.7	125.3	445.1	75.4	147.2	8,110.5	14,049.2
Mean		135.4	3.3	11.7	2.0	3.9	213.4	369.7
Percent		36.6	0.9	3.2	0.5	1.0	57.7	100.0

Table 4. Catch abundance during the 2001 Kamishak Bay District scallop survey.

Tow number	Station	Animals per nautical mile: Whole scallops	Tanner crabs	King crabs	Fishes	Total catch
01101	E06	361.3	119.8	0.0	5.4	486.5
01102	G02	25.0	66.0	1.0	6.0	98.0
01103	G04	349.5	217.8	2.0	21.8	591.1
01104	E02	141.2	278.4	0.0	18.6	438.2
01105	A02	8.0	153.0	0.0	12.0	173.0
01106	C06	64.0	298.0	0.0	14.0	376.0
01107	C10	202.9	173.5	2.0	7.8	386.3
01108	C02	7.9	159.4	0.0	16.8	184.2
01109	E04	331.7	224.8	1.0	17.8	575.2
01110	C04	35.6	174.3	1.0	9.9	220.8
01111	G06	349.0	62.0	1.0	13.0	425.0
01112	C08	258.3	612.6	0.0	21.4	892.2
01113	E10	32.7	86.5	0.0	13.5	132.7
01114	G10	0.0	0.0	0.0	20.0	20.0
01115	E08	252.0	656.0	0.0	16.0	924.0
01116	G08	30.7	10.9	1.0	20.8	63.4
01117	H03	30.0	28.0	0.0	17.0	75.0
01118	F03	357.9	75.7	0.9	21.5	456.1
01119	B03	40.0	119.0	0.0	4.0	163.0
01120	B07	8.9	82.2	0.0	5.9	97.0
01121	B11	8.8	150.0	1.0	11.8	171.6
01122	D09	209.0	915.0	0.0	23.0	1,147.0
01123	D07	403.0	392.1	0.0	9.9	805.0
01124	D05	284.2	312.9	0.0	16.8	613.9
01125	F05	513.9	121.8	0.0	25.7	661.4
01126	H05	16.7	16.7	0.0	5.9	39.2
01127	B05	52.9	290.2	0.0	25.5	368.6
01128	F01	9.9	158.4	0.0	34.7	203.0
01129	H07	13.0	4.0	1.0	23.0	41.0
01130	F07	444.1	218.6	1.0	10.8	674.5
01131	H09	1.0	7.1	0.0	5.1	13.1
01132	F09	168.0	153.0	0.0	14.0	335.0
01133	A04	5.0	560.0	0.0	15.0	580.0
01134	B09	158.8	709.8	1.0	19.6	889.2
01135	F11	0.0	0.0	0.0	3.0	3.0
01136	D11	217.0	34.0	0.0	1.0	252.0
01137	A10	2.1	186.2	0.0	9.6	197.9
01138	E12	5.9	36.6	0.0	11.9	54.5
Total	n = 38	5,400.0	7,864.3	13.8	549.4	13,827.4
Mean		142.1	207.0	0.4	14.5	363.9
Percent		39.1	56.9	0.1	4.0	100.0

Table 5. Size distribution of weathervane scallops captured during a dredge survey in the Kamishak Bay District, 2001.

	Number of Scallops (scallops per nautical mile)																		
	Shell Height Class (mm)																		
Tow	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	Total
01101	0	0	0	0	1	0	2	2	2	11	15	30	92	127	53	26	1	0	361
01102	0	0	0	0	0	0	0	0	2	0	0	1	5	5	6	3	4	0	26
01103	0	1	2	1	0	2	3	3	9	20	18	20	57	92	79	38	5	0	350
01104	0	0	5	0	0	1	4	1	4	3	4	9	44	39	23	4	1	0	141
01105	0	0	0	0	0	1	0	0	0	0	0	0	2	2	2	0	1	0	8
01106	0	0	0	0	0	3	1	0	0	0	1	2	12	11	13	15	3	1	62
01107	0	0	0	0	0	3	7	4	0	2	3	13	37	70	37	19	7	1	202
01108	0	2	0	1	0	0	1	0	0	0	0	0	1	1	2	0	0	0	8
01109	0	0	2	0	0	0	2	2	5	9	5	15	105	111	55	18	2	1	332
01110	0	0	0	0	0	5	1	0	0	0	0	0	5	9	7	8	1	0	36
01111	0	0	0	0	0	1	0	0	2	0	3	19	81	130	88	23	1	1	349
01112	0	0	2	1	0	2	2	2	0	2	2	3	42	75	62	47	14	4	258
01113	0	5	2	0	3	3	4	2	0	1	1	5	3	1	4	0	0	0	33
01114	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01115	0	0	2	4	0	0	1	1	1	1	4	24	55	76	52	26	4	1	252
01116	0	0	0	0	0	0	1	1	0	0	2	1	3	7	6	8	2	0	31
01117	0	0	0	0	0	0	0	0	1	1	1	2	4	4	7	10	0	0	30
01118	0	0	1	0	0	0	10	4	6	24	14	27	121	96	36	16	1	2	358
01119	0	0	0	0	0	1	0	0	0	0	0	0	8	9	16	5	0	1	40
01120	0	0	0	0	0	1	0	0	0	1	0	1	3	0	3	0	0	0	9
01121	0	1	1	0	0	2	2	1	0	2	0	0	0	0	0	0	0	0	9
01122	0	0	6	4	1	2	9	5	3	4	6	8	46	61	34	18	1	1	209
01123	0	0	3	1	0	1	0	1	0	5	5	19	99	126	99	43	2	0	403
01124	0	0	0	0	3	0	3	3	4	1	1	20	67	77	63	34	8	0	284
01125	0	0	3	1	4	0	7	2	18	33	26	78	179	124	31	8	1	0	514

Table 5. (page 2 of 2)

	Number of Scallops (scallops per nautical mile)																		
	Shell Height Class (mm)																		
Tow	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	Total
01126	0	0	0	0	0	0	0	0	0	1	1	3	3	3	4	2	0	0	17
01127	0	0	0	0	0	0	0	0	0	0	0	0	2	19	17	14	0	2	53
01128	0	0	0	0	0	0	0	0	0	0	1	3	2	2	2	0	0	0	10
01129	0	0	0	0	0	0	0	0	0	0	1	2	3	2	1	0	1	0	10
01130	0	0	1	0	0	0	2	1	2	11	17	62	124	138	75	10	2	0	444
01131	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01132	0	0	5	0	0	1	3	0	1	3	3	29	61	44	15	4	1	1	171
01133	0	0	1	0	0	0	0	0	0	0	0	1	1	2	0	0	0	0	5
01134	0	0	2	0	1	2	1	0	1	1	2	14	42	38	46	8	1	0	159
01135	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01136	1	4	1	0	0	3	5	1	2	4	4	19	60	51	56	11	0	0	222
01137	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	2
01138	0	0	1	1	0	2	2	0	0	0	0	0	0	0	0	0	0	0	6
Total	1	13	40	14	14	36	72	35	62	139	139	428	1,371	1,551	994	415	63	16	5,402
Percent	0.0	0.2	0.7	0.3	0.3	0.7	1.3	0.7	1.1	2.6	2.6	7.9	25.4	28.7	18.4	7.7	1.2	0.3	100.0

Table 6. Age distribution of weathervane scallops caught in a dredge survey in the Kamishak Bay District, 2001.

	Scallop Age Class (years)																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
Tow	Number of Scallops (scallops per nautical mile)																				
01101	0	1	19	5	12	85	16	57	42	22	12	17	19	18	15	14	3	2	3	0	361
01102	0	0	1	1	1	3	1	4	1	0	0	1	0	0	4	3	4	1	0	1	26
01103	4	5	29	14	11	53	24	38	28	16	5	18	32	23	13	21	11	5	1	1	350
01104	5	5	6	3	6	31	14	24	19	8	0	5	4	7	2	3	0	0	1	0	141
01105	0	1	0	0	0	0	0	0	0	2	2	1	1	0	0	0	1	0	0	0	8
01106	0	4	0	0	2	10	2	12	3	3	2	3	3	3	1	3	9	1	1	0	62
01107	0	9	5	6	4	34	15	27	13	18	7	8	12	14	10	12	7	3	1	0	203
01108	2	2	0	0	0	0	0	0	2	1	0	0	0	1	0	0	0	0	0	0	8
01109	2	2	12	5	6	76	29	68	20	22	9	20	21	12	12	11	3	1	1	1	332
01110	0	6	0	0	0	2	1	2	1	4	0	3	2	4	6	3	1	1	0	0	36
01111	0	1	3	2	7	61	29	58	35	25	12	24	25	14	20	20	5	3	4	1	349
01112	3	3	6	1	2	29	17	29	16	18	5	14	31	21	26	18	12	3	1	4	258
01113	7	12	1	0	2	4	2	1	0	2	0	1	0	1	1	0	0	0	0	0	33
01114	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01115	4	4	2	3	7	51	18	37	21	12	9	11	17	20	14	13	8	1	0	0	252
01116	0	1	2	0	1	1	8	1	2	0	0	0	3	4	0	2	2	2	2	0	31
01117	0	0	1	0	0	9	0	1	2	1	1	0	0	1	4	6	2	0	2	0	30
01118	1	11	22	18	7	103	11	64	33	19	7	12	16	7	9	2	9	1	3	2	358
01119	0	1	0	0	0	4	1	6	4	1	2	6	3	3	2	2	4	1	0	0	40
01120	0	1	0	1	0	3	1	0	1	0	0	0	0	0	0	2	0	0	0	0	9
01121	2	4	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
01122	8	14	11	5	3	26	12	40	16	12	5	8	8	4	13	9	9	3	3	0	209
01123	3	2	5	2	8	74	31	58	38	25	11	29	28	24	18	18	16	7	4	4	403
01124	0	6	8	1	5	52	21	48	19	18	8	15	20	11	21	17	9	3	1	3	284
01125	3	14	37	25	28	150	44	78	37	25	17	20	12	9	6	8	2	1	1	0	514

Table 6. (page 2 of 2)

	Scallop Age Class (years)																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
Tow	Number of Scallops (scallops per nautical mile)																				
01126	0	0	2	1	1	4	1	4	2	1	0	0	0	0	0	0	0	1	0	0	17
01127	0	0	0	0	0	1	1	3	6	2	5	6	10	5	3	6	5	0	1	0	53
01128	0	0	0	0	2	4	0	0	1	2	0	0	0	0	0	0	0	1	0	0	10
01129	0	0	1	0	1	6	0	0	1	0	0	0	0	1	0	0	0	0	0	0	10
01130	1	1	12	8	26	125	27	80	33	25	16	12	28	13	21	7	7	2	1	0	444
01131	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01132	5	3	3	5	10	53	11	31	13	7	5	4	8	3	6	1	3	0	0	0	171
01133	1	0	0	0	0	0	0	1	0	1	2	0	0	0	0	0	0	0	0	0	5
01134	2	4	3	2	1	31	8	26	17	21	4	10	7	5	8	8	2	0	1	0	159
01135	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01136	6	8	9	2	4	41	21	26	20	13	7	6	13	15	11	9	5	2	4	0	222
01137	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
01138	2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Total	60	129	201	110	156	1,128	364	825	443	323	152	252	321	242	245	217	138	44	35	17	5,403
Percent	1.1	2.4	3.7	2.0	2.9	20.9	6.7	15.3	8.2	6.0	2.8	4.7	6.0	4.5	4.5	4.0	2.6	0.8	0.7	0.3	100.0

Table 7. Meat recovery during a weathervane scallop survey in the Kamishak Bay District, 2001.

Date	Number of tows	Number of scallops	Weight (kg) Whole	Weight (kg) Meat	Percent Recovery
May 12	6	106	55.3	3.2	5.8
May 13	6	109	49.0	3.2	6.6
May 14	7	143	56.7	3.6	6.4
May 15	7	133	58.1	3.7	6.3
May 16	6	71	31.8	2.1	6.7
May 17	3	46	18.1	1.2	6.8
Total	35	608	268.98	17.12	6.37[a/]

a/ Total percent recovery - calculated as a weighted average using daily recovery weighted by daily whole weight.

Table 8. Sex composition and maturity of weathervane scallops sampled from a dredge survey of the Kamishak Bay District, 2001.

Maturity	Sex (number of scallops) Unknown	Male	Female	Total	Percent
Spawning	0	291	275	566	96.4
Nonspawning	11	3	7	21	3.6
Total	11	294	282	587	100.0
Percent	1.9	50.1	48.0	100.0	

Table 9. Fish catch abundance during the Kamishak Bay District scallop survey, 2001.

Common Name	Scientific Name	Fish/nmi		Percent
		Total	Mean	
Arrowtooth Flounder	*Atheresthes stomias*	13.9	0.4	2.5
Butter Sole	*Isopsetta isolepis*	278.6	7.3	50.7
Dover Sole	*Microstomus pacificus*	6.9	0.2	1.3
Eelpout	Family Zoarcidae	4.9	0.1	0.9
Flathead Sole	*Hippolossoides elassodon*	55.6	1.5	10.1
Poacher	Family Agonidae	5.0	0.1	0.9
Prickelback	Family Stichaeidae	9.0	0.2	1.6
Rex Sole	*Glyptocephalus zachirus*	20.7	0.5	3.8
Rock Sole	*Lepidopsetta bilineata*	2.0	0.1	0.4
Ronquil	Family Bathymasteridae	6.0	0.2	1.1
Sand Skate	Gernera Bathyraja	9.8	0.3	1.8
Sand Sole	Family Plueronectidae	1.0	0.0	0.2
Sculpin	Family Cottidae	27.6	0.7	5.0
Searcher	Family Bathymasteridae	21.8	0.6	4.0
Snailfish	Family Liparidae	27.6	0.7	5.0
Starsnout	Family Agonidae	4.1	0.1	0.7
Starry Flounder	*Platichthys stellatus*	4.0	0.1	0.7
Sturgeon Poacher	Family Agonidae	47.1	1.2	8.6
Walleye Pollock	*Theragra chalcogramma*	2.9	0.1	0.5
Wrymouth	Family Cryptacanthodidae	1.0	0.0	0.2
Total		549.5	14.5	100.0

Table 10. Summary of the weathervane scallop survey in Kamishak Bay, 1984-2001.

Year	Defined bed (nmi^2)	Stations sampled	Survey CPUE (kg/nmi)	Population biomass (mt)	Population abundance	Meat recovery
1984	56	47	21.9	940	2.0 million	10.10%
			No Surveys - 1985-1995			
1996	52	26	63.0	2,485	3.2 million	8.50%
1997			No Survey			
1998	58	14	63.6	2,803	8.0 million	7.09%
1999	58	28	99.6	4,236	11.5 million	6.55%
2000			No Survey			
2001	52	25	92.1	3,637	8.0 million	6.37%

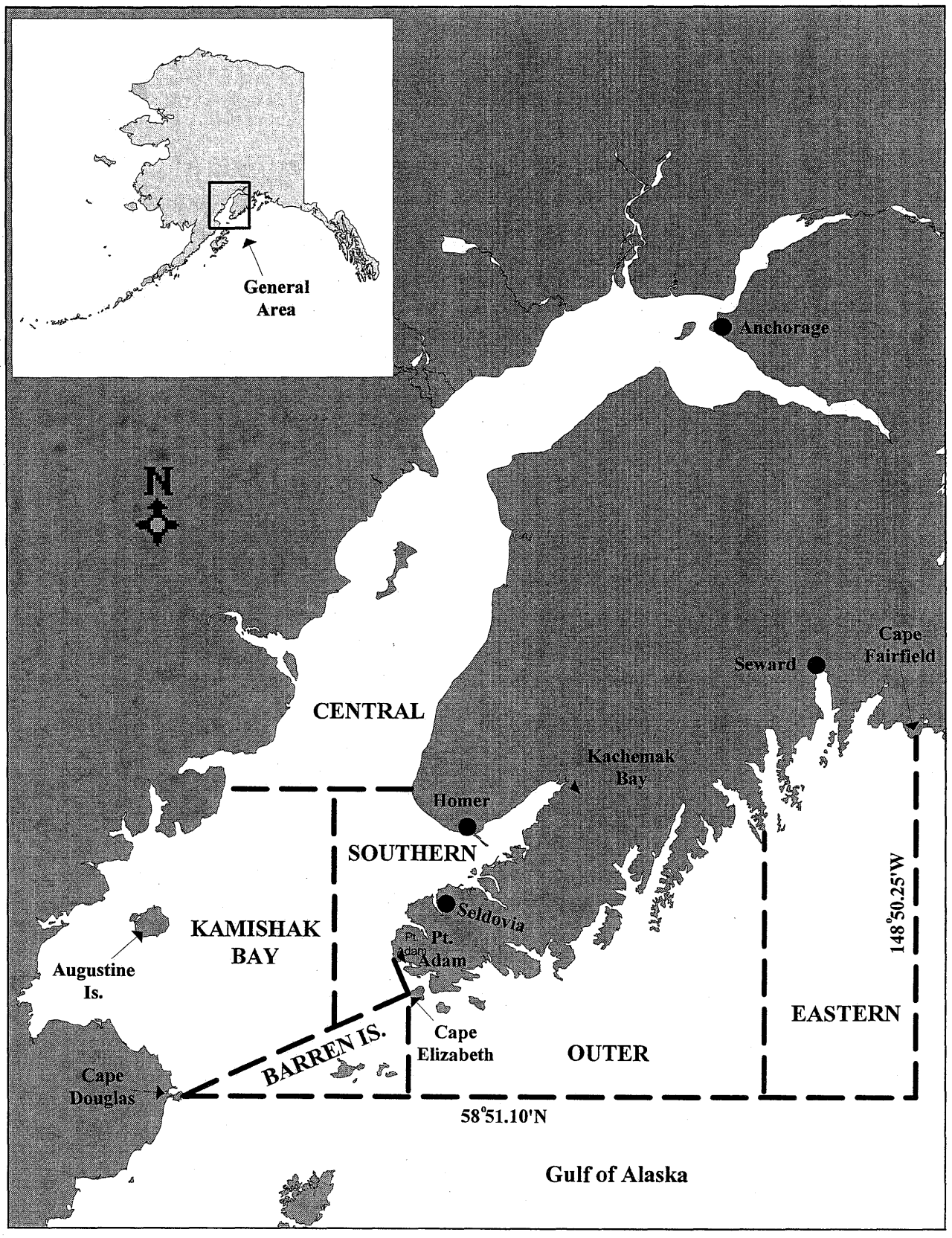

Figure 1. Commercial shellfish fishing districts of the Cook Inlet Management Area.

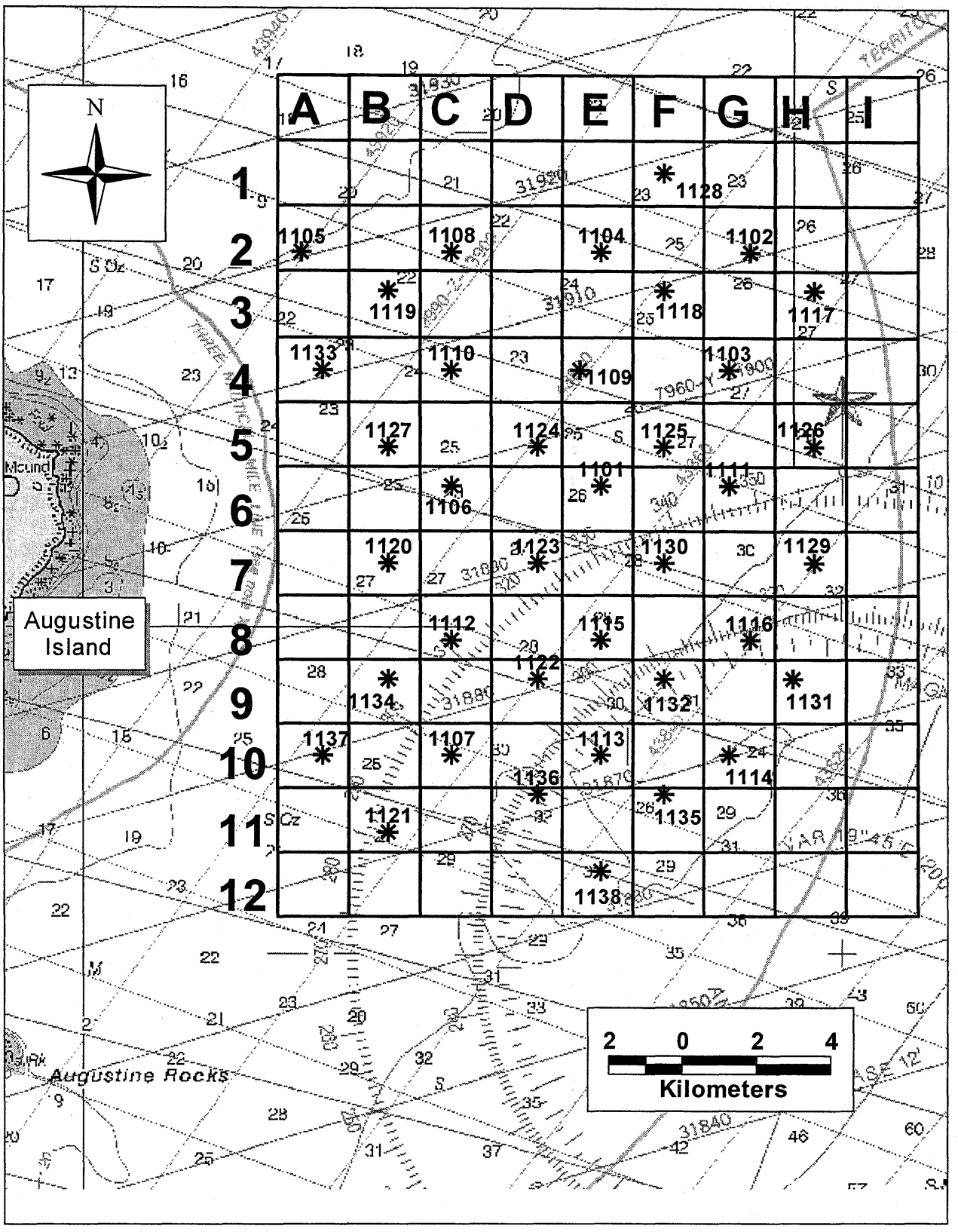

Figure 2. Mid-points of dredge tows within the general survey grid of 1.0 nmi^2 showing potential sample stations for the 2001 Kamishak Bay scallop survey.

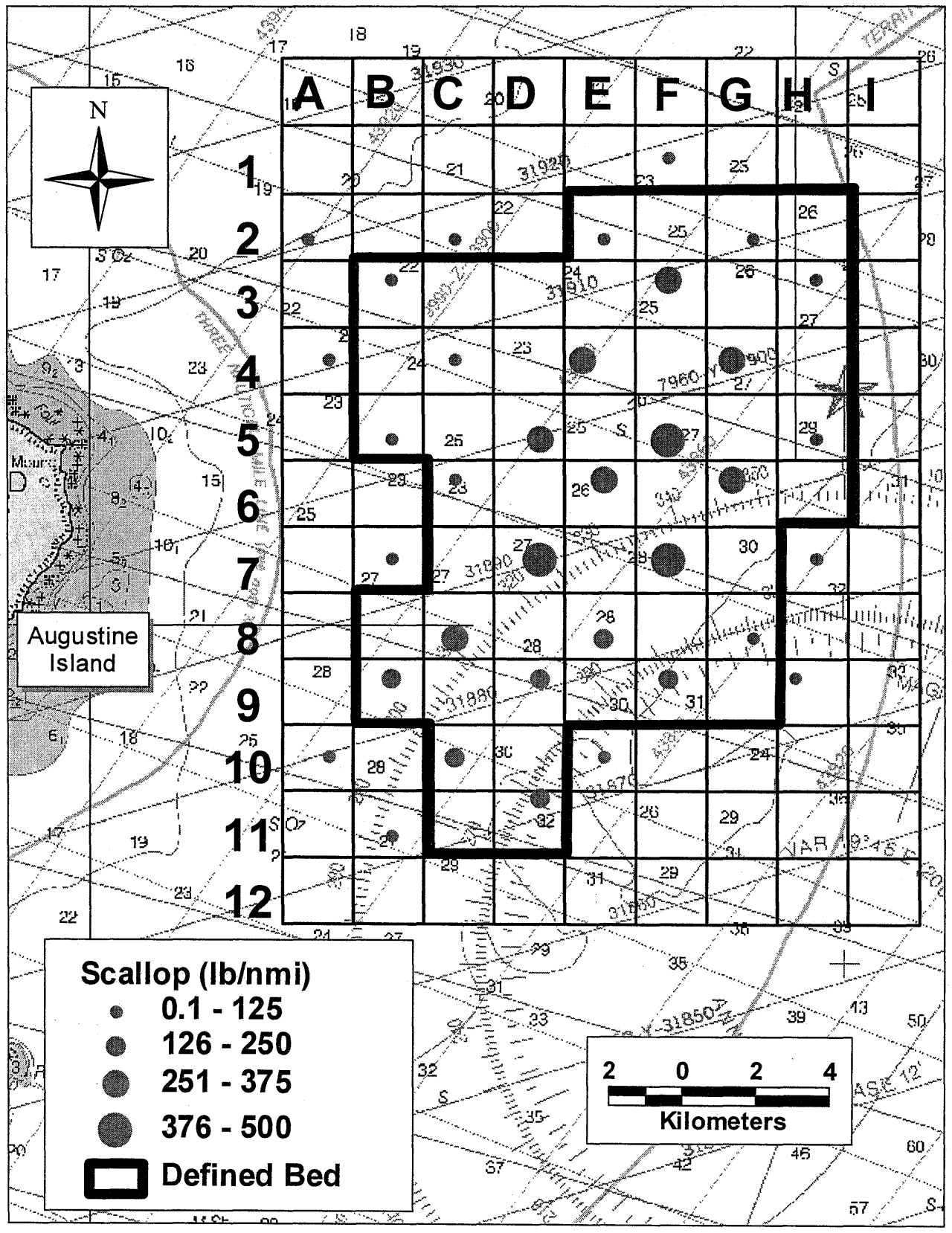

Figure 3. Distribution of weathervane scallops during a scallop survey in the Kamishak Bay District, 2001.

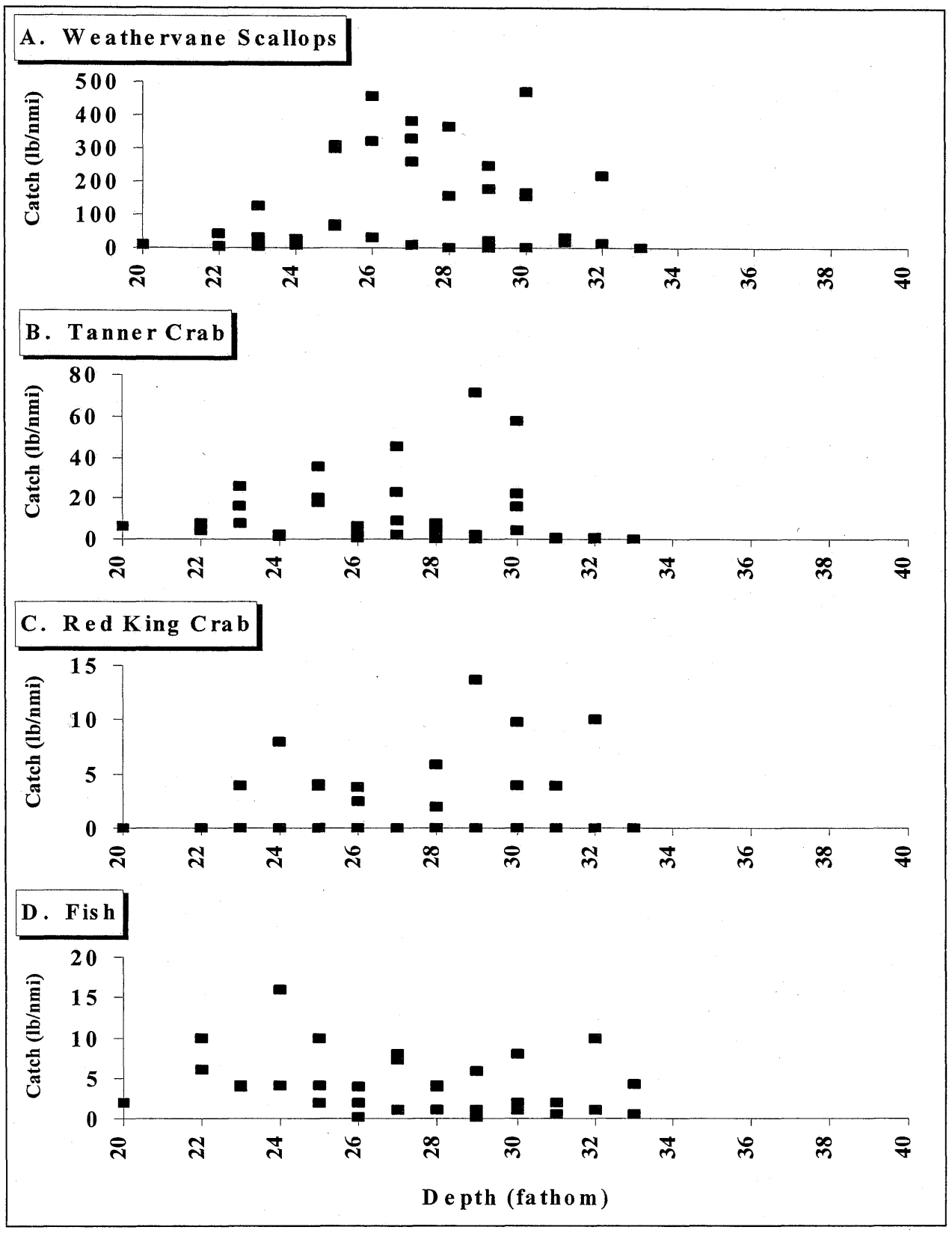

Figure 4. Distribution of catches by depth for (A) scallops, (B) Tanner crab, (C) red king crab, and (D) fish in the 2001 Kamishak Bay scallop survey.

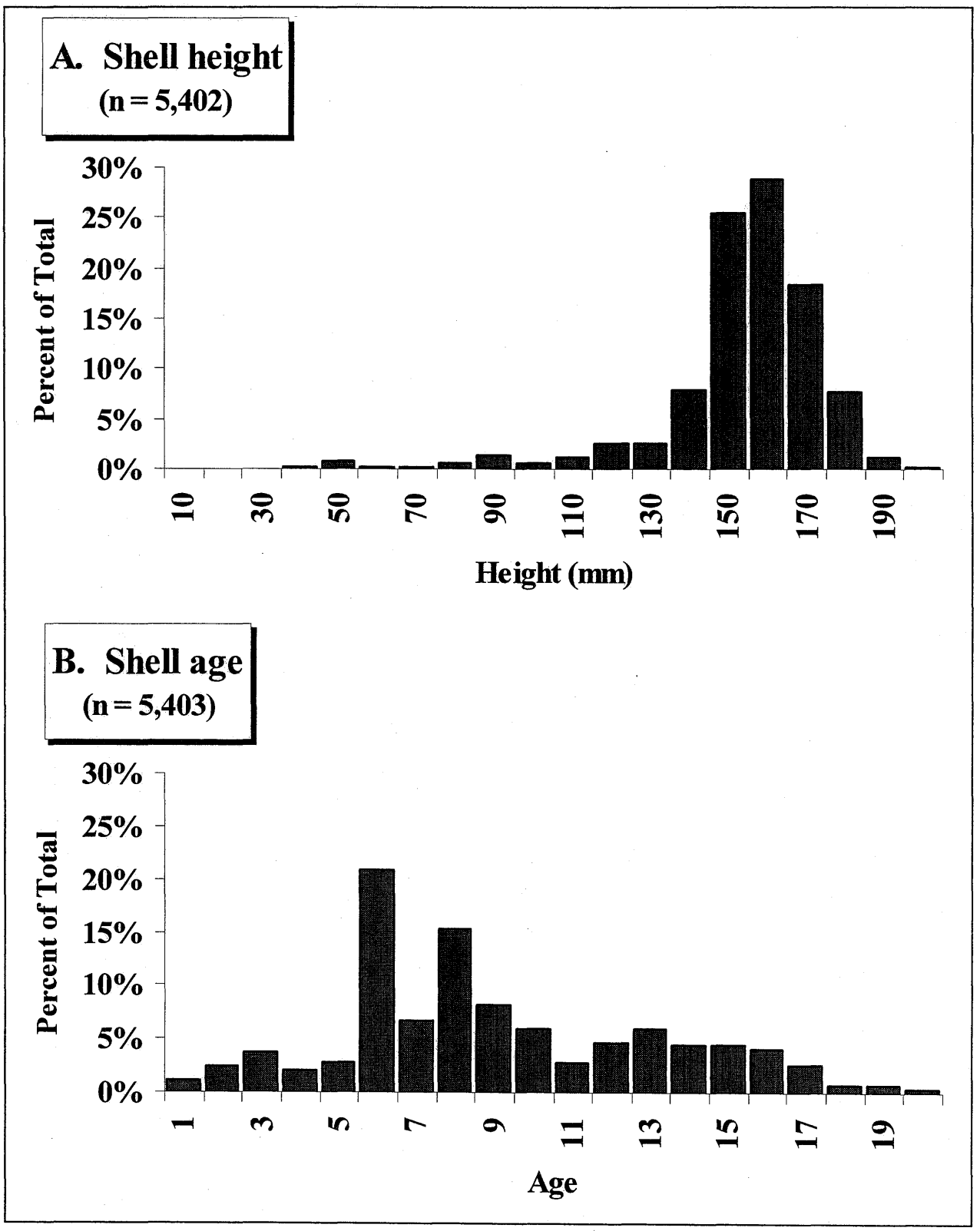

Figure 5. Shell height (A) and age (B) distribution of weathervane scallops caught during a dredge survey of the Kamishak Bay District, 2001.

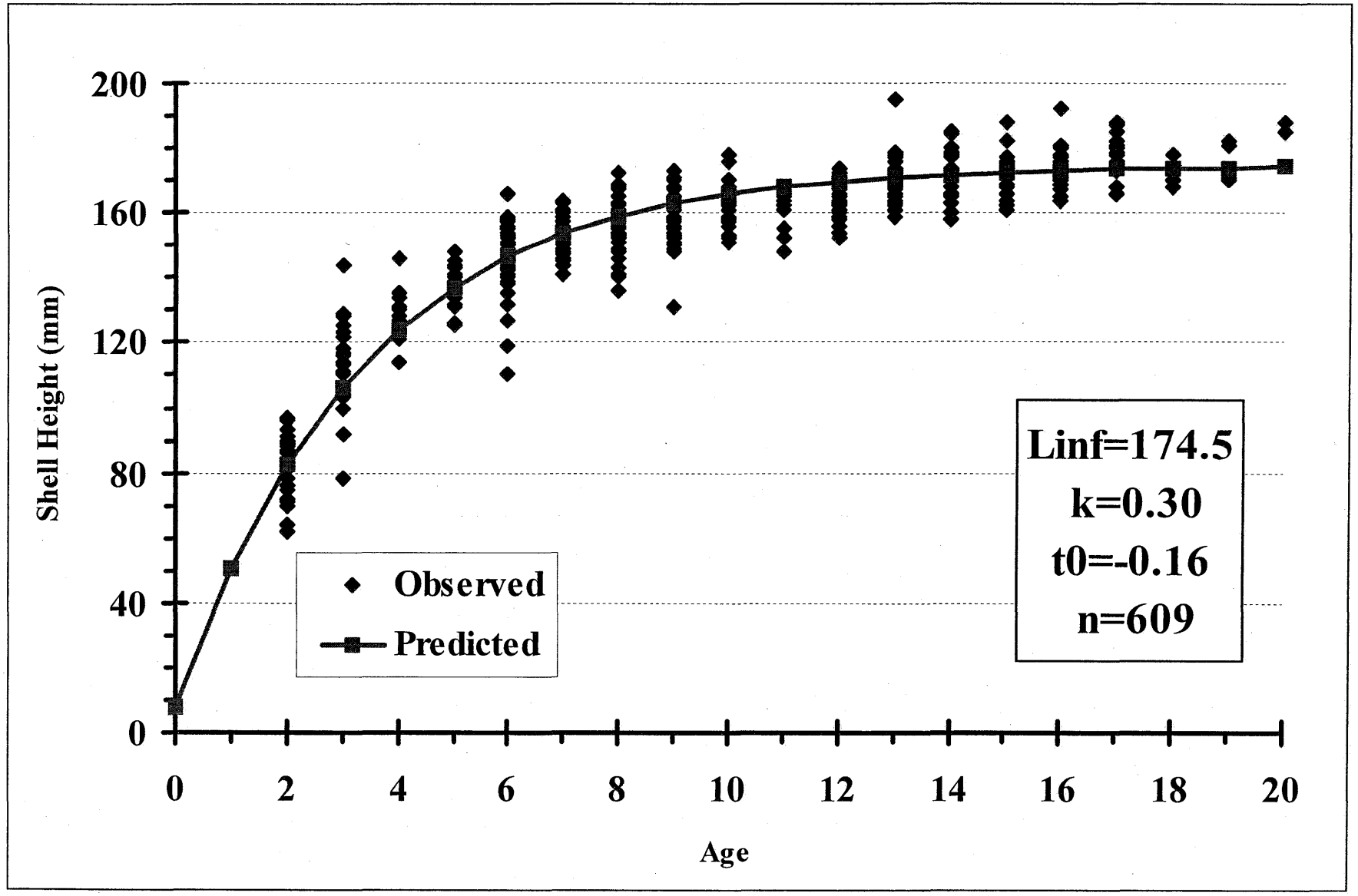

Figure 6. Height-at-age for weathervane scallops caught during a dredge survey of the Kamishak Bay District, 2001.

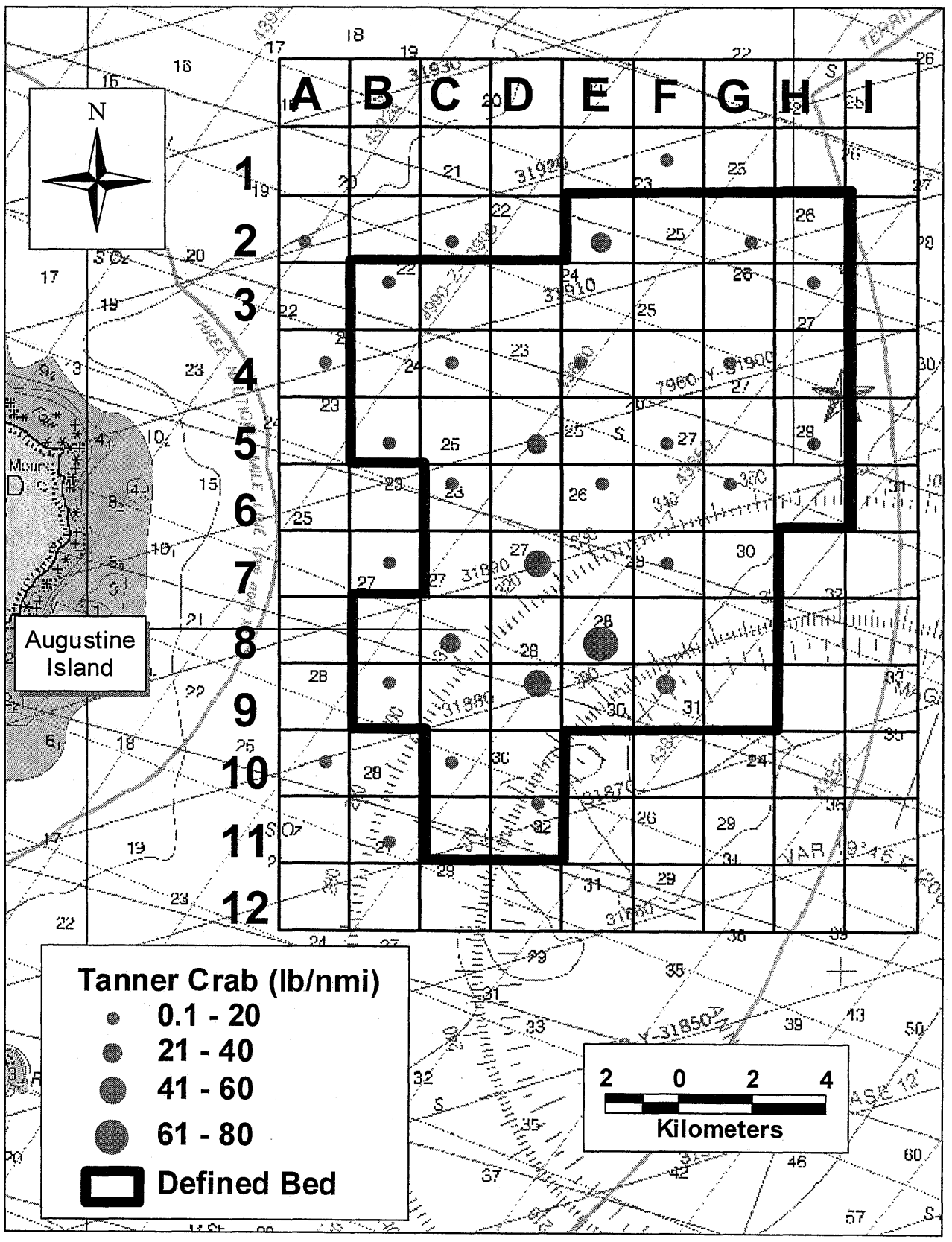

Figure 7. Distribution of Tanner crab during a scallop survey in the Kamishak Bay District, 2001.

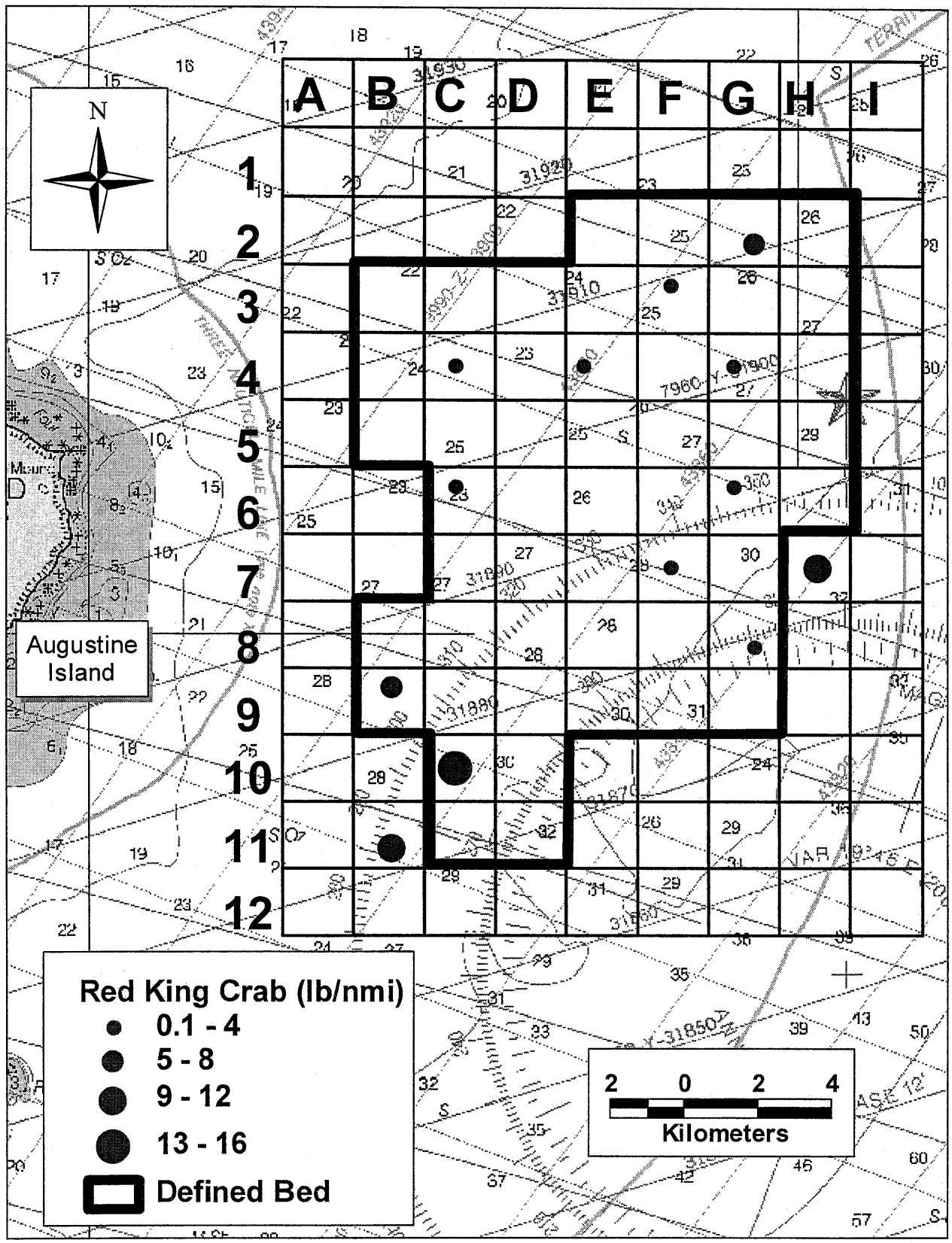

Figure 8. Distribution of red king crab during a scallop survey in the Kamishak Bay District, 2001.

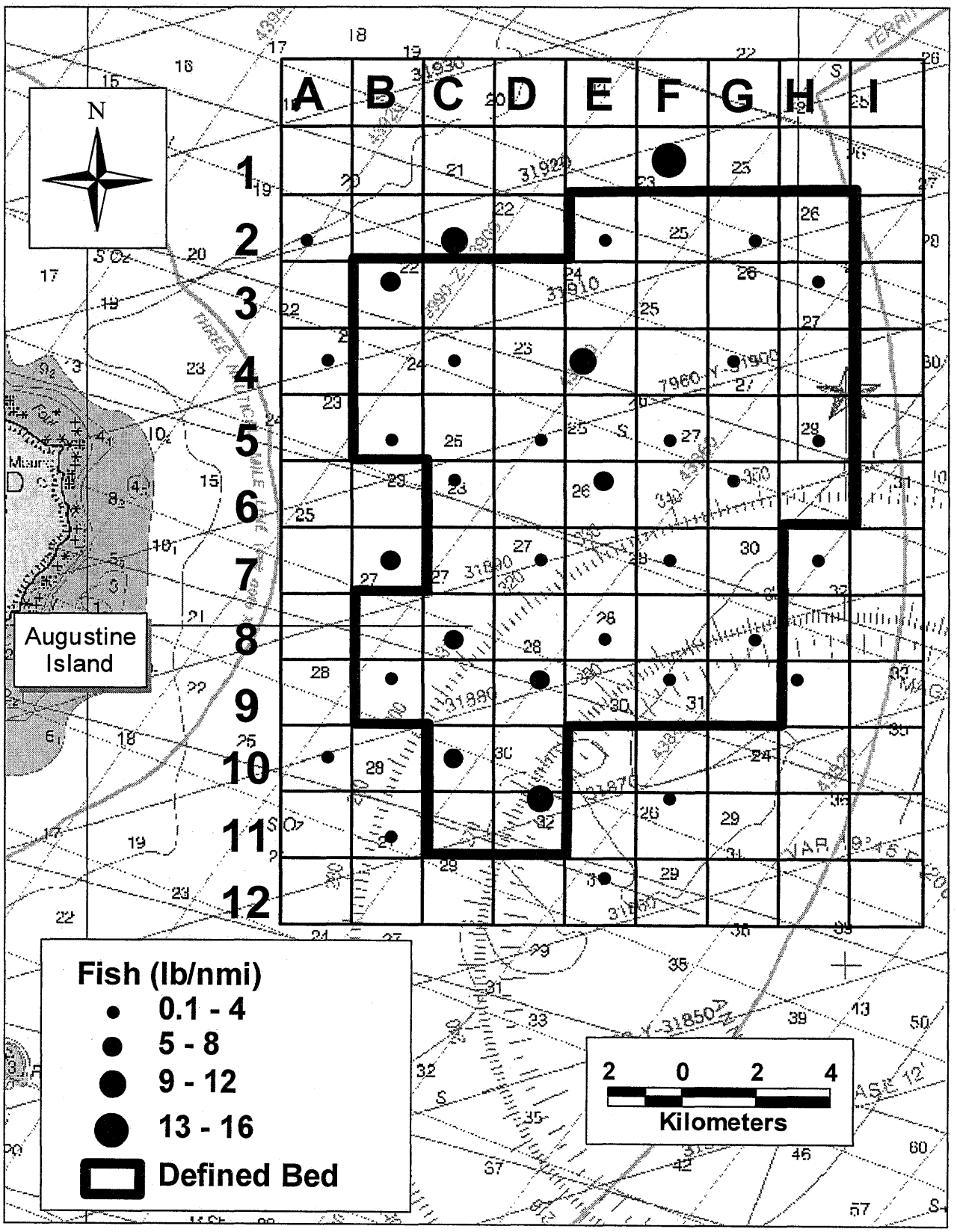

Figure 9. Distribution of fish catches during a scallop survey in the Kamishak Bay District, 2001.

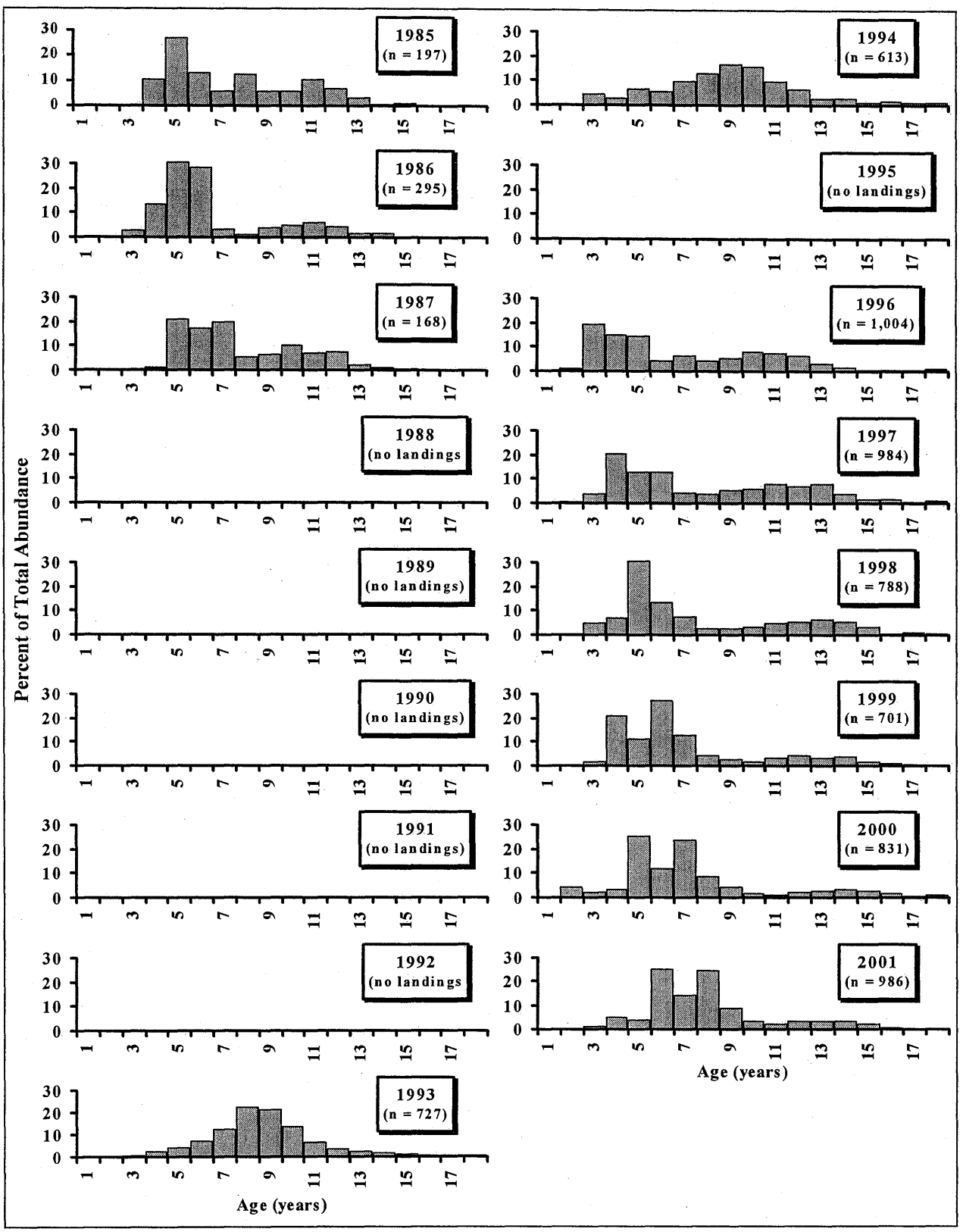

Figure 10. Age composition of weathervane scallops from Kamishak Bay commercial harvests, 1985-2001.