A Comparison of the Efficiency, Cost, and Data Integrity of Electronic Data Capture and Written Methods During the Red King Crab Stock Assessment Survey in Southeast Alaska

by

Peter G. van Tamelen

REGIONAL INFORMATION REPORT NO.[1] 5J03-03

Alaska Department of Fish and Game
Division of Commercial Fisheries
P.O. Box 25526
Juneau, Alaska 99802

March 10, 2003

[1] The Regional Information Report Series was established in 1987 to provide an information access system for all unpublished divisional reports. These reports frequently serve diverse ad hoc informational purposes or archive basic uninterpreted data. To accommodate timely reporting of recently collected information, reports in this series undergo only limited internal review and may contain preliminary data; this information may be subsequently finalized and published in the formal literature. Consequently, these reports should not be cited without prior approval of the author or the Division of Commercial Fisheries.

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ABSTRACT

Electronic devices are a ubiquitous component of our society but field biologists have been slow to adopt these new technologies into their work. The use of electronic data collection devices was investigated during the 2002 red king crab stock assessment survey in Southeast Alaska. A number of different data collection options were considered and one was implemented using a Handspring™ handheld computer in a waterproof case with electronic calipers. The advantages and disadvantages of various systems are discussed. Because of the importance of the survey data to the management of the fishery, the electronically collected data duplicated the data collected by written means. The intent of this study was to assess the time required by both methods to sample and to convert the data into computer format, the cost to the State of Alaska to collect the data, and integrity of the data using both electronic and written data collection methods.

To convert the data from crab measurements to computer format, electronic sampling was about 3 times faster than written methods with most of the savings resulting from the elimination of the data entry and editing processes. Additionally, if the 3 biologists on the survey all used electronic data collection methods, the time required to sample the pots could have been reduced by about half, resulting in the potential to increase the sample size of the survey or pursue other related projects. Compared to written methods, a cost savings of about 60% could have been realized if electronic data collection methods were used, but the actual savings, $5000, is small relative to the cost of the entire survey, almost $78,000. There were few discernable differences between the data collected by the two methods, and those that were detected could be attributable to intersampler variability. Even with a prototype data collection system, which had a very small screen and was somewhat cumbersome to use, large savings in time and money could have been realized with little effect on the data collected. The limitations of the system used can easily be overcome with different equipment and careful attention to programming.

INTRODUCTION

Electronic devices are now an integral part of our society and have found their way into virtually all aspects of our lives. The reason for this prevalence is that electronics can make mundane tasks easier and more accurate . One general exception to this invasion of electronics is the recording of data in field situations for the biological sciences (Krueger and Rich 2001). Although some projects have devised ways of recording relevant physical data, such as temperature, wind speed, currents, and wave force, using dataloggers (Denny 1982; Helmuth 1998), few projects have used electronic devices to record biological measurements. Traditionally, in the field, biologists would record their data on data sheets with pencils. Then they would enter these data into computers after returning from the field. This procedure can generate errors at any of a number of data transfer stages (Helms 2001). Data entry errors can be reduced dramatically by implementing some simple, quality control procedures, such as data editing, comparing a hard copy of the entered data to the original data sheet by either one or two people, or double data entry and comparing the two electronic datasets and identifying differences. Although these procedures can catch many or all of the data entry errors, they do nothing to detect or eliminate errors that occur between the measurement of the organism and the data sheet. In addition, these quality control procedures are time consuming and tedious. Collection of field data by electronic means can eliminate the tedious and time-consuming process of data entry and associated quality control. In addition, electronic data collection has the potential to reduce some of the errors generated between the organism and the data sheet, depending upon how the data are collected. If the measurement is made with an electronic device, the data recorder, as well as any interpretation by the measurer, is eliminated.

Electronic devices, mostly handheld computers, also know as Personal Digital Assistants (PDAs), have been used successfully in medical (Hyde 1998; Hammond and Sweeney 2000; Apkon and Singhaviranon 2001; Bliven et al. 2001) and retail sales (Stone and Hollier 2000; Boyer et al. 2002) industries. Most reports indicate that it takes less time to capture the same data relative to written methods and users generally prefer the electronic versions. By saving time, sample sizes in projects using electronic devices can be increased, resulting in better estimates of sample means and reducing the need for accuracy in collected data (Zschokke and Luden 2001). Sacrificing data accuracy for larger sample sizes can result in better estimates (Meese and Tomich 1993), but using electronic devices for data collection can potentially increase sample size while simultaneously increasing accuracy, by using instruments with higher resolution, and reducing errors generated during data transfer steps. Despite these potential benefits, no published study has yet compared the efficiency and data accuracy of electronic data collection methods for field biology.

This study evaluated the use of electronic data capture devices during the 2002 red king crab stock assessment survey in Southeast Alaska. Electronic devices were investigated, purchased, and prepared for use during the survey. Because the survey is vital to the management of the fishery, all data were collected using written methods and comparative data were collected via electronic methods. The two methods were compared for efficiency of data collection, data entry, cost to the State of Alaska, and quality of data.

MATERIALS AND METHODS

Red King Crab Stock Assessment Survey

The annual red king crab stock assessment survey has been ongoing for more than 20 years and is probably one of the longest running crab pot surveys in the world (Clark et al. 2002). The survey is generally conducted during June and July and surveys about nine different areas in northern southeast Alaska by setting 300-500 pots. When pots are hauled, all commercially important crabs are sampled. When there are large catches, crabs may be subsampled at rates that are determined in the field. Crabs are measured for either carapace length (king crabs, *Lithodes aequispinus* and *Paralithodes* spp.) or width (Tanner, *Chionoecetes bairdi*, and Dungeness, *Cancer magister*, crabs), their shell condition is classed into one of five categories (light, soft, new, old, and very old), the condition of their legs is noted as being normal, one leg missing or regenerated, or two or more legs missing or regenerated, and parasites are noted. The most common parasite encountered is infection of Tanner crabs by a dinoflagellate and causing bitter crab disease (Meyers et al. 1987). In addition, female crabs are evaluated for percent clutch fullness, egg development, and egg condition. Other variables of interest, such as legal size or other morphometric measurements, may be incorporated into the survey. Also, data regarding the set and pull times of the pot, incidental species captured, pot condition, and pot location and depth are recorded.

Currently, there are three forms used for the crab survey. The data regarding individual crabs are recorded on a crab specimen form that is used for all crab surveys and species in the region. Pot set and haul times, location, and depth are recorded on the skipper log form, and information about pot condition, substrate, and other species is recorded on the incidental species form. After the data have been recorded on these forms, it is entered into computer format using a regional database program. The data are then edited by comparing a printout of the data to the original data forms. Generally, the data are entered and edited on the same day they were collected. The data are then used to estimate the population size and health in each area surveyed.

The survey is usually divided into three separate legs, each lasting about 9-12 days, with each leg covering 3 areas. In the past, the state operated vessel, R/V *Medeia*, has been used for these surveys, but this year the first leg was conducted onboard a chartered fishing vessel, F/V *Cape Reliant*. Three biological crew perform all of the sampling and make decisions regarding the conduct of the scientific research.

Hardware Devices[1]

I investigated a number of different devices for collecting and storing data. These devices range widely in capabilities, price, and durability. The ideal hardware device would be intuitive to operate, interface easily with existing personal computer (PC) software, have various interfaces to collect data, be water resistant, and able to handle our data needs.

[1] Use of trade names does not constitute endorsement by the Alaska Department of Fish and Game but serves only to document equipment used.

Handheld computers have many of the attributes needed in a data collection device (Krueger and Rich 2001). They are small and intuitive to operate, and they exchange data with a personal computer in a matter of seconds with the touch of a button termed the 'HotSync®' operation. This HotSync® operation is a two-way data exchange so that information flows from the handheld computer to the computer as well as the other way. This allows programmers to change values in lookup tables, for example, on one central computer and this change would then be distributed to all handheld computers when they are HotSync®ed. Additionally, various devices can be attached to handheld computers via their ports used for HotSync®ing. One brand, Handspring™, also has a proprietary port in addition to their HotSync® port where various modules can be easily attached. A large variety of modules exist including bar code scanners, global positioning system receivers, serial ports, camera lenses, memory upgrades, backup modules, and many others. Handheld computers can easily handle our data needs for field sampling because they use compact software and data storage protocols allowing them to store a large amount of data in a fairly small amount of memory. Finally, handheld computers are inexpensive, starting at about $100 for the version that I tested. Despite all of these positive attributes, handheld computers have a number of drawbacks. First, few, if any units are water resistant. This can be overcome by the use of water resistant cases that can take the form of premanufactured units to sandwich bags. Second, the operating system (OS) most units use, Palm™ OS, is highly proprietary and is subject to the whims and vagaries of the Palm™ Company. Third, the units are very small, making more complex data capture tedious. Small screens lead to small "buttons" that can be easily missed or miskeyed resulting in error generation. A larger screen would solve this problem. Finally, they are designed to be used with two hands, one hand holds the unit while the other uses a stylus to input data and control programs. If both hands are occupied operating the handheld computer, it makes sampling difficult. I decided that the advantages of handheld computers outweigh the disadvantages, so I pursued this option using a Handspring™ brand unit after briefly investigating other options.

Some handheld computers have larger screens and these typically run on an operating system other than Palm™ OS, either Windows® CE or Linux. Windows® CE, although a bit more familiar to Windows® users, is memory intensive relative to Palm™ OS, resulting in larger units and shorter battery life. The use of Windows® CE currently lags behind Palm™ OS in the number and types of units available. Linux, although a relative newcomer to the handheld computer format, offers some advantages. It is compact, similar to Palm™ OS, has the flexibility found in Windows® CE, and it is under public domain. Although some Linux handheld computers are currently available, it remains to be seen if this operating system becomes popular. I chose to use the most ubiquitous system currently available, Palm™ OS, for two main reasons. First, it is unlikely that such a common system with so many users would become entirely obsolete when new technologies are developed. Second, a common operating system will have more software options available than less common systems. Thus, if any one software package does not entirely satisfy our needs, then the potential for finding different and more suitable software is higher with a common operating system. Finally, Windows® CE and Linux devices tend to be much more expensive than the Palm™ OS devices, starting at about $300.

In addition to handheld computers, there are at least two other types of devices that show promise as data capture devices in the field. First, waterproof computers are currently available and water resistant versions of the common laptop computer have all of the functionality of a personal computer. Various additional items can be purchased to go with these units, including custom keyboards that can be specific to various projects, as well as any electronic device with a RS232, USB, or other standard computer connection. These devices are highly appealing but are also very expensive with prices starting at about $5,000. Second, there are numerous devices designed to meet the needs of industry for inventory tracking or similar tasks. Often these devices have a built-in bar code scanner but can also accept data via a keypad or touch screen. These units are often rugged and customizable and have many of the same advantages as handheld computers. Their main drawbacks are that the interface with personal computers is more complex than that of a handheld computer, often requiring some special programming. The interface is also a one-way connection so information only goes from the device to the computer. This would require programmers to modify all units when a change is needed. A final drawback is that the software that is available to run on these units can be limited in availability and scope.

Software

Once I decided to use handheld computers to collect data, I needed to decide upon the software to use. Currently, the software available for handheld computers is growing rapidly as people begin to realize the capabilities of these devices. I did not spend much time investigating the different database and spreadsheet programs available for handheld computers, but took the advice of a colleague in California that has been using handheld computers for data capture. The database program I investigated was HanDBase® that is available for about $30. This program is a simplified database program that has both PC and handheld computer interfaces. It allows easy export to more popular spreadsheet and database programs, such as Microsoft Excel®, Microsoft Access®, and Oracle®. The handheld computer interface allows for data entry from both bar code and the manual methods provided by the handheld computer and accessories. After obtaining the program, it took me about a day to learn the program and develop user interfaces specific to crab surveys including a specimen form and a combination skipper and incidental species form. To use this program, the Handspring™ handheld computer needed to have a bar code scanner installed in the springboard module slot, limiting the data input to bar codes and manual inputs. The program does allow for pop-up values for the categorical variables, but these proved unwieldy and I decided to generate bar codes for all of the crab data. A major disadvantage to the HanDBase® program is that it could not be programmed to default values to the previous record; the program only can default to a preset value. Thus, whenever the categorical values for a crab differed from the default values the data would need to be entered for each crab. The software developer is in the process of developing a new release of HanDBase® that will allow the default values to be taken form the previous record. HanDBase®, however, does not allow the use of electronic calipers. See Appendix A for a list of useful websites.

When this project was initiated, electronic calipers did not have good water resistance. When the main bar of the caliper was wet, the calipers would give faulty readings. Since then, new calipers have been developed that use electronics that are not affected by water and the electronics housing has become more resistant to water and dust. It is important in the future to get calipers that utilize a magnetic induction sensing system. To date, I have found only one manufacturer of a Handspring™ module that allows calipers to be connected to the handheld computer utilizing their software, DataGet®. The connection works with the software provided but did not work with third party software such as HanDBase®. The DataGet® software was designed for measuring parts for quality control in manufacturing plants. Although not specifically designed for biological work, DataGet® was easily adapted for use in crab surveys. Additionally, the software developer can modify the program to make it better suited for crab surveys. This software can default values to the previous record, so if we measured several male red king crabs that were all in the same condition, we would only need to take the measurement for each crab without having to reenter all of the categorical variables for every crab. Finally, DataGet® can download data directly to Microsoft Excel® spreadsheets or Access tables with each HotSync® operation.

In addition to commercially available applications, it is possible to develop custom applications that perform exactly to our specifications. There are numerous programming languages that allow the development of custom applications that are readily available. If possible, it may be useful to develop a custom application that interfaces directly with our regional database and that takes advantage of the two-way HotSync® link between the handheld and personal computers. If there was some change that needed to be made to the database it could be made on one computer and distributed to the handheld computers via the HotSync® operations.

Data Input Hardware

There are a number of options that allow the generation of new data. Because humans often make errors in reading, interpretation, or outputting data, either verbally or by some other means, it is desirable to remove human errors whenever possible. To eliminate human errors, it would be ideal to have electronic devices generate data directly from a crab specimen. This may ultimately be possible for some or all of the data, but it is currently unrealistic. The best we can do is to minimize the human errors to every extent possible. For crab surveys, we record a number of different variables for each crab. There are two types of variables we assess for each crab: 1) categorical variables, such as species, sex, shell condition, and parasites, that have a limited number of values, and 2) continuous variables such as length, width, and weight that are measured. The categorical variables currently require an evaluation, often subjective, by the sampler while the continuous variables are measured by a tool under the control of the sampler. These two types of data can either be handled differently or similarly when gathering the data electronically.

The two methods of electronic data collection that I investigated, bar code scanning and electronic calipers, treated the data similarly or differently. Bar code scanning is a rather old technology that essentially has developed alphabets and numeric characters that can be easily read by computer devices rather than human eyes. These characters are composed of alternating light and dark stripes that vary in their widths. Bar code scanners read these characters by two different methods. First, the scanner consists of small, pencil-like wand that is swiped over the bar code, and the second is handheld device that uses a laser to scan the bar code from a distance. The advantage to wands is that they can be used in situations where the bar codes can become obscured, by fish slime for example, and the wand will both clear the offending material and read the bar code with a single swipe. The disadvantage is that the bar code is read only once, so the chance of a misread is fairly high. The handheld scanners, on the other hand, will scan a bar code about 40 times per second and will only generate a number when numerous scans give the same value, essentially eliminating the chance of a misread. There are numerous bar code fonts with various advantages and disadvantages. Some fonts consist only of numbers while others contain numbers, letters, and special characters. The choice of font should be directed by the needs of the user and the application. Most fonts have start and stop characters allowing the bar code to be read backwards or forwards and will give the same result; a wand scanner passed one way over the bar code will yield the same result if passed in the other direction. The advantage of bar code scanning is that it almost eliminates the possibility of miskeying values and it may prove useful for data entry in the office as well as in the field. The disadvantage to bar codes for crab surveys is that it would require a large number of bar codes to be arrayed tightly on one sheet to encompass all of the needed variables. The space between bar codes would be small so the chance of scanning the wrong bar code would be increased. Although errors generated by misscanning would be small if the bar codes were arranged appropriately; a true length of 147 mm may get misscanned as 146 or 148 mm but it would be almost impossible to scan it as 174 mm, a common human error.

For the continuous variables, using electronic devices to measure or weigh the crabs offers the advantage of eliminating all human handling of the data. With electronic calipers, the sampler does not need to read the value, just place the calipers appropriately and press a button. Electronic scales offer the same advantage as calipers in stable conditions, such as in a laboratory on land. On a vessel at sea, however, electronic scales are affected by even gentle rocking of the boat. This rocking does not allow the scale to stabilize and the sampler needs to interpret the scale readings by taking the midpoint between high and low values displayed by the scale. Electronic measuring devices are thus preferable over bar codes for continuous variables but do not allow the entry of categorical variables. Categorical variables can be entered using menus generated by software associated with the device being used to collect the data, although miskeying of these menus is a possibility. A hybrid system that uses electronic measuring devices to collect continuous variables and bar codes for categorical variables would utilize the best of both technologies.

System Used

After much deliberation, I used a Handspring™ Platinum handheld computer fitted with a DataGet® module and software with Mitutoyo™ calipers. The handheld computer was housed in a waterproof Otter box with a custom cutout to accommodate the module and cord to the calipers. The calipers were 8" (208 mm) Mitutoyo™ Absolute Waterproof electronic calipers fitted with a Mitutoyo™ cable with a send button built-in. During sampling I would hold the calipers and a stylus in one hand and handle the crabs with the other hand. After each pot, data were downloaded by removing the handheld computer from the case and performing a HotSync® operation. The downloaded data contained words describing the categorical variables, while we have historically used numbers. I used Microsoft Excel® to convert the raw data into the more familiar number format. This conversion process involved copying the raw data into the conversion spreadsheet and then copying the converted data into a final spreadsheet. Appendix A lists websites to many of the products used and investigated in this project.

The total cost for this system was about $770 for one person. This included $130 for the handheld computer, $300 for the DataGet® software and module, $200 for the calipers, $60 for the caliper cable, and $80 for the waterproof case. In comparison, the cost to supply a sampler for written sampling includes $200 for a pair of calipers, and the cost of Rite-in-the-Rain™ paper and printing the forms that was about $300 for the entire summer, so the cost-per-sampler was about $100. Thus it costs about $470 more to supply an electronic sampler compared to a traditional sampler.

Efficiency Comparison

The time required to collect the data in either written or electronic format was recorded opportunistically throughout the summer. For written data, a timer was started when the first crab was measured by the sampler and stopped when the last crab was measured and the data was recorded. This procedure did not include the sorting phase of sampling in which crabs are initially sorted by species and sex. Because all data was recorded for the entire project in this manner, even a small subsample of the time required to measure the crabs in each pot provided a sufficient sample size to make comparisons to the electronic data collection system.

The author collected electronic data whenever time permitted. The electronically sampled pots generally included those with moderate catches and when the sampling would not unduly impede the progress of the survey. Because different numbers of people were involved in the different phases and methods of sampling, all time was converted to person seconds, the number of people times the number of seconds, or person hours, the number of people times the number of hours.

The time required to enter the data was recorded only for people experienced with entering data into the regional database. The total time required to enter one day of sampling (typically 20 pots) was recorded, and the sampling time required per crab and pot was then calculated. After the data is entered into the regional database, it is common practice to edit the data by having one person read the original data out loud while another person checks the data on a printout of the electronic data. Any detected errors are then corrected. The time required for editing was recorded and the time per crab and per pot was calculated. The time required to transfer the electronic data from the handheld computer to a personal computer was assumed to be 60 seconds per pot and was considered negligible per crab. To remove the handheld computer from the waterproof case, put it into the cradle, press the HotSync® button, and to wait for the transfer took about one minute. To transfer the original data from the HotSync® process into a format recognizable by the regional database required the user to copy the data from one Microsoft Excel® spreadsheet into another that was set up to transform the data from words into codes. Because the system was not designed to transfer data into the regional database, the time required for this procedure was not calculated.

After calculating all of the time required to get the crab data into a final computer format, I calculated the cost to the state for paying various personnel likely to be involved in the crab surveys. This cost included all pay, benefits, and sea duty pay but not hazard pay. Hazard pay was not included because it is relatively minor and not all employees are eligible to receive hazard pay aboard vessels. The cost per employee was calculated for each day or minute to allow for various assumptions about the cost to the state. Finally, the cost to the state was calculated for each crab, pot, and for the entire survey. I assumed that the biological crew consisted of a fisheries biologist II, a fisheries biologist III, and a fish and wildlife technician III and that the vessel crew consisted of a boat officer (BO) IV, two BO IIIs, and one BO II.

Data Comparison

In order to compare the data collected from both methods, both types of data were sorted by sample number (pot), species, sex, and size of crab. All samples were checked to insure that they contained equal numbers of crabs; occasionally a crab was measured using written methods and then tossed overboard before being electronically measured and these crabs were removed from the written data. Sorting by size was an efficient way to match up the crabs, but some crabs of similar size would be reversed and the associated data would not correspond. In these cases, the associated data were corrected by hand to allow comparisons of the same crabs. After matching up the crabs by this size sorting procedure, the differences between the written and electronic (written – electronic) data were calculated for size, and percent clutch fullness. The categorical variables, shell condition, parasite condition, and leg condition, were also compared.

Throughout the summer, a total of 8,680 crabs caught in 495 pots were measured during the survey, and 387 crabs (4.4%) and 24 pots (4.8%) were also sampled electronically. The time taken to sample 92 (18.6%) pots using written methods was recorded. There were 24 sampling days during the survey and I obtained the time to enter data on 5 (20.8%) and to edit data 7 (29.2%) of those days.

The time required to sample for each of the two methods were compared using t-tests after checking the homogeneity of variances using the F_{max} test (Sokal and Rohlf 1995) and applying a log transformation when necessary. To compare continuous data, the electronic data were subtracted from the written data for each set of paired values and the resulting values were compared to zero with a one-sample t-test. Categorical variables were compared using a Wilcoxon signed ranks test for paired data. All statistical tests were performed using S-Plus 6.0 software.

RESULTS

Efficiency Comparison

The time required to sample all crabs in a pot was significantly less for electronic methods compared to written methods (Figure 1). On average, it took 3 people working about 300 seconds (= 900 person seconds) to sample all of the crabs in a pot compared to about 400 seconds for one person using electronic methods. The data entry and editing required an additional 220 and 254 person seconds per pot for written methods. The total time, in person seconds, required to sample the crabs from one pot and get the data in electronic format was about 3 times higher for written methods compared to electronic methods. Comparing the time required to sample each crab yielded results very similar to the pot comparisons. Not only were data entry and editing virtually eliminated with electronic sampling, it took about 25 person seconds to sample each crab using electronic methods and significantly longer, about twice the time, for written methods (Figure 1). The total time to gather these data was about 3 times higher for written compared to electronic methods. Consequently, the total cost to the State of Alaska to collect and enter these data was also about 3 times higher for written methods compared to electronic methods for both standard work days (SWDs) and regular days off (RDOs) (Table 1).

To extrapolate to the whole survey, only the per crab data was used because pots with large catches generally were not sampled with electronic methods due to time constraints. During the 2002 survey a total of 8,680 crabs were measured. The total time needed to measure these crabs and convert the data into electronic format was calculated to be 184.6 person hours for written methods and 60.4 person hours for electronic methods. The total cost to the state was approximately $7,930 for written methods and would have been about $2,987 for electronic methods, using the actual schedule and assuming the crabs were evenly distributed among the SWDs and RDOs on which we sampled. The total cost of the survey, however, was much greater than either of these values. The total calculated survey costs include biological crew time, vessel crew time, and the charter vessel cost but ignores state vessel operation and maintenance costs and miscellaneous supplies, and was calculated to be about $77,743. If the R/V *Medeia* had been used on leg 1 rather than the charter vessel, the cost would have been about $74,287, with the biological crew costs accounting for about 40% of the total. During the survey, about 630 person hours of biologist time were spent at sea. If written methods were used about 445 person hours were available for other duties including bait chopping and preparation, pot setting, and other projects. If electronic methods were used the additional time available to biologists would have been about 570 person hours. Including the additional time required to set and retrieve pots, I estimated that the sample size could have increased from 495 pots to 563 pots.

Accuracy Comparison

Most of the electronically recorded measurements were within 1.0 mm of the written measurements (Figure 2). The largest observed difference was just over 4 mm. The difference between written and electronic data, however, was significantly larger than zero, indicating that written methods produced slightly larger measurements by about 0.08 mm. The percent clutch fullness was also significantly greater for written methods compared to electronic methods with an average difference of 6.8% (Figure 2). There was no difference for most crabs, and the largest observed difference was 60%.

The shell conditions in about 10% of the crabs were evaluated differently using the two methods (Table 2), and no shell age was more than one category different. There was no significant difference in shell age among the paired samples. The electronic methods classed significantly more crabs with one or more legs missing or regenerated (Table 1). About 10% of the crabs had leg classification differences. Of the 318 Tanner crabs measured using both methods, 47 were classed as having bitter crab disease by written methods, and 43 were similarly classed by electronic methods. A total of 6 individual crabs were classed differently.

DISCUSSION

The system I used performed well and was easy to learn. The software and software menus were intuitive and made sense. One advantage of the electronic data system is that numeric codes were all replaced with verbal descriptions of the characters being described. For example, what we currently refer to as a "shell 3, leg 2, parasite 6"crab using written methods is more descriptively called a "new shell, bitter crab with one leg missing" using the electronic system. The use of codes is so prevalent in the crab survey that all but the most experienced personnel got confused at some point and had to refer to the posted code keys. The elimination of numeric codes, wherever possible, will result in easier to learn systems. Another advantage of the electronic sampling system was that the calipers could be read while still on the crab, eliminating any errors generated by removing the calipers from the crab and then reading them visually. While sampling, I never looked at the display on the calipers before pressing the "send" button. After sending the reading to the handheld computer, I glanced at the handheld computer to confirm that the reading was about right. This made measuring the crab faster and more accurate.

The system I used had some minor disadvantages. The screen on the handheld computer was very small and required the use of a stylus, and this made data entry somewhat tedious. A larger screen that could be manipulated with gloved hands, similar to those used in restaurants, would be ideal. This system was not attached or held to the sampling table so that keeping track of the handheld computer, and keeping it in a convenient location took some effort. This could easily be solved by making a holder for the handheld computer that kept it at a convenient height and location. Screen size is currently being addressed by the computer industry, and I have seen larger handheld computers on the market with handheld devices that have screens that are about 10 inches in diagonal measurement.

These units currently sell for about $1,000 each or less, and this price should drop if they become popular. The cord that connected the handheld computer to the calipers was accessible to the crabs and often was pinched by the crabs or got tangled in the crab legs and spines. If the calipers were supported on a retractable cord so that they could be pulled down to take a measurement but would retract up when not in use, this problem would be solved. Finally, I occasionally forgot to change one or two of the categorical variables back to their prior value after sampling an odd crab. For example, if one Tanner crab had bitter crab disease, I would change the disease category to reflect this but then forget to change it back when I finished with that crab, making all the subsequent crabs recorded as having bitter crab disease when they really did not. This problem could be solved in one of two ways. First, a "standard" crab could be programmed in and all crabs that differ from the standard would need to be changed. Ideally, the standard crab could be changed from location to location. Second, the computer could be programmed with a check screen that would give the appropriate information and ask if this is correct before finally logging the data. Another improvement would be to implement a simple data checking system that would highlight or flag values that were out of some predetermined range.

Although it took longer for one person using electronic methods to sample crabs compared to 3 people using written methods, the sampling rate could increase about by 2 fold by having 3 people sample simultaneously. In this way, the total sampling time could be reduced to about 8.4 seconds per crab. This would speed up the sampling process, allowing the vessel to move to the next pot sooner than is now possible. Currently, the vessel is required to remain where the pot was pulled until all of the red king crabs have been measured and returned to the sea. If the time to sample pots is thus reduced, it would be possible to increase the number of pots set and hauled each year. Increasing the sample size would benefit the biomass estimates by reducing variability.

The total time taken to convert data from crabs into electronic format was much less using electronic methods resulting in substantial cost savings to the State. Although these cost savings are minimal compared to the total costs of the survey, implementation of electronic data gathering would give the biologists more time to perform other tasks or to initiate additional projects such as genetics sampling, larval collector deployment and retrieval on the buoy lines, habitat quantification, or other projects.

The data collected by both methods was generally very similar. There were no major differences in width or length measurements, and only 5 crabs of the 387 crabs measured had differences larger than 2.0 mm and none were greater than 5.0 mm. With the methods used, it is impossible to determine which method resulted in an error. Using electronic methods it is virtually impossible to take measurements smaller than the true value because the value was sent to the handheld computer while the calipers were still in place on the crab. In contrast, the written calipers are generally removed from the crab and then read and this could result in either under- or overmeasurement if the calipers are not carefully removed from the crab. The other data evaluated in this study was all somewhat subjective in nature, and the observed differences probably reflect variations between observers more than differences between methods of recording. The differences observed in clutch fullness can be attributed to the authors' tendency to estimate lower clutch fullnesses. The differences in leg condition may be attributable to the fact that more time is spent looking at each crab using electronic methods than written methods, giving more time to notice various leg conditions. The differences observed between the two data collection methods were minor and would not have had any significant effect on subsequent population analyses. For these analyses, crabs are classed into various size, sex, and shell age categories before doing any calculations, and the variations observed in this study would have had very little effect on this classification procedure.

Another advantage to electronic data collection methods is that they dramatically reduce the number of steps where errors can be generated. Using written methods an error can be produced in any of many steps including, 1) the sampler may misread the caliper or the caliper could have moved when it was removed from the crab, 2) the sampler may say a different number than they read, 3) the recorder may hear a different number than was spoken, especially in a noisy situation, 4) the recorder may write a different number than they heard, especially with data being recorded rapidly, 5) the data entry person may misread the number written by the recorder, and 6) the data may be entered incorrectly and not detected during the editing process. In the red king crab survey, there have been a number of cases, after data editing, where the width measurements were recorded in the length column or vice versa, reflecting the different biological measurements of Tanner and king crabs and the use of a "one size fits all" data entry program. These errors were only detected during analysis after editing, but other errors may be present that are not ever detected despite the data editing process. In contrast, electronic methods eliminate many or all of these potential sources of error, so they are inherently more accurate.

Even with the small and somewhat cumbersome setup used in this study, the use of electronic data capture would have resulted in substantial time savings with virtually no loss of data integrity. The system used was entirely composed of "off the shelf" components with very little time invested in developing project specific hardware or software. Many of the problems encountered during this study can easily be overcome. The small screen can be fixed by using one of the new handheld computers manufactured by ViewSonic or Spectre that have 10" screens. Another alternative is to use the same technology used in some restaurants with touch screen computer monitors. A bigger screen with bigger buttons would also eliminate the use of a stylus in the sampling procedure because fingers, even gloved, could be used. Some of the problems encountered with forgetting to switch a categorical variable back to a more standard value could also easily be solved with appropriate programming. One way to do this would be to have a standard crab as the default rather than the previous crab, so that switching from leg condition 2 to 1 is automatic and the user only needs to record those crabs that are missing legs. Another improvement would be to have individual forms for each crab species and sex that include only the variables relevant to that type of crab. An ideal interface would go to a graphical representation of a standard crab and the sampler would measure the specimen then touch appropriate parts of the crab to change the values. For example, if a sampler were measuring Tanner crabs, a picture of a Tanner crab would appear on the screen after the sampler selected the type of crab, the measurement could be displayed on the picture after it was sent, and then the sampler could tap on the legs that are missing and these would lighten or disappear. The final picture would then be pictorial version of the crab in hand.

The technologies that enable the collection of data electronically are evolving rapidly and the procedures for collecting data will only become more reliable and easier. Many of the newer handheld computers now have integrated wireless technologies allowing the immediate transfer of data from the handheld computer to a support computer. If this wireless link is 2-way, then the data validation procedures programmed into a database can be used while processing crabs by giving immediate feedback to the sampler.

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Table 1. The cost estimates for written and electronic data capture for all the crabs in one pot (per pot) and for individual crabs (per crab). For all values the mean and standard error (SE) are given. Written sampling had 3 people sampling, one person entering data, and two people editing data. Only one person was involved in the electronic data capture throughout the process. Costs were calculated for all people doing each task and assumed that a fisheries biologist II, III, and fisheries technician III were participating in the survey and were calculated for both standard work days (SWD) and regular days off (RDO) and includes both regular and sea duty pay.

	Per Pot				Per Crab			
	Written		Electronic		Written		Electronic	
Cost (SWD)								
Sampling	$9.98	($0.74)	$4.80	($0.86)	$0.52	($0.03)	$0.29	($0.02)
Data Entry	$1.76	($0.36)	$0.70	($0.00)	$0.13	($0.02)		
Data Edit	$2.50	($0.32)			$0.12	($0.01)		
Total	**$14.24**		**$5.50**		**$0.78**		**$0.29**	
Cost (RDO)								
Sampling	$18.00	($1.33)	$8.70	($1.57)	$0.95	($0.05)	$0.53	($0.03)
Data Entry	$3.12	($0.64)	$1.27	($0.00)	$0.23	($0.04)		
Data Edit	$4.49	($0.58)			$0.22	($0.02)		
Total	**$25.61**		**$9.97**		**$1.40**		**$0.53**	

Table 2. The number of crabs classed into the various shell age categories using both written and electronic sampling methods. The crabs that were classed with the same shell age with both methods are in bold. There was no difference in the shell age classification between the two methods (Wilcoxon signed-rank test, Z= 0.9729, P = 0.3306).

	Electronic					
Written	Soft	Light	New	Old	Very Old	Total
Soft	**0**	2	0	0	0	2
Light	0	**7**	4	0	0	11
New	0	11	**261**	10	0	282
Old	0	0	6	**73**	0	79
Very Old	0	0	0	5	**8**	13
Total	0	20	271	88	8	387

Table 3. The number of crabs classed with various leg condition categories using both written and electronic sampling methods. The crabs that were classed with the same leg condition with both methods are in bold. Legs that were in the process of regeneration were classed as missing. There was a significant difference in leg condition classification between the two methods (Wilcoxon signed-rank test, Z= 3.1116, $P = 0.0019$).

	Electronic				
Written	Normal	1 missing	≥2 missing	Abnormal Carapace	Total
Normal	**238**	28	2	0	268
1 missing	8	**64**	3	0	75
≥2 missing	1	2	**39**	0	42
Abnormal Carapace	1	0	0	**1**	2
Total	248	94	44	1	387

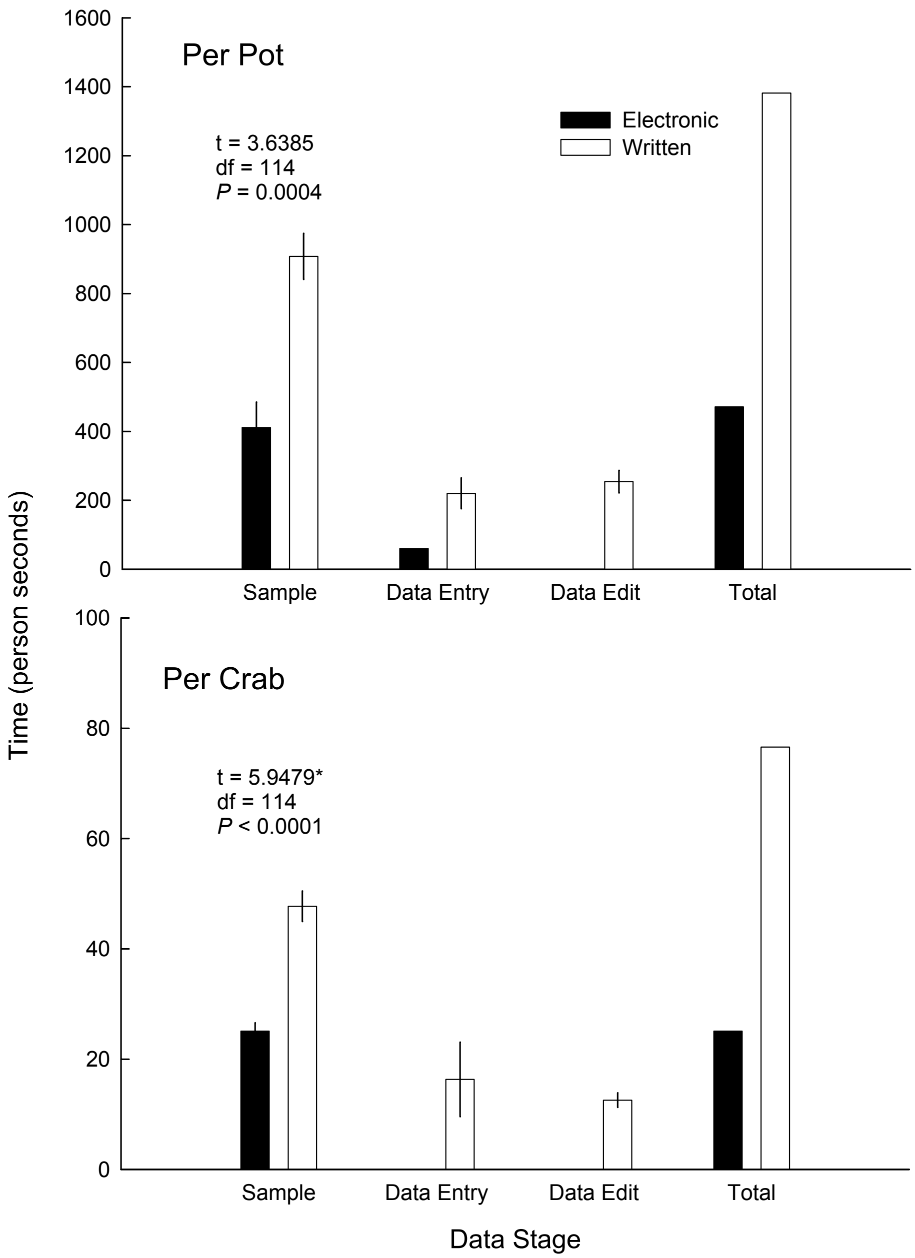

Figure 1. The mean time required for each step of data gathering for both electronic and written methods. Error bars represent one standard error of the mean. The total time required to get the data from crab into computer format is the sum of the averages of all stages. An * indicates the test was done on log-transformed data.

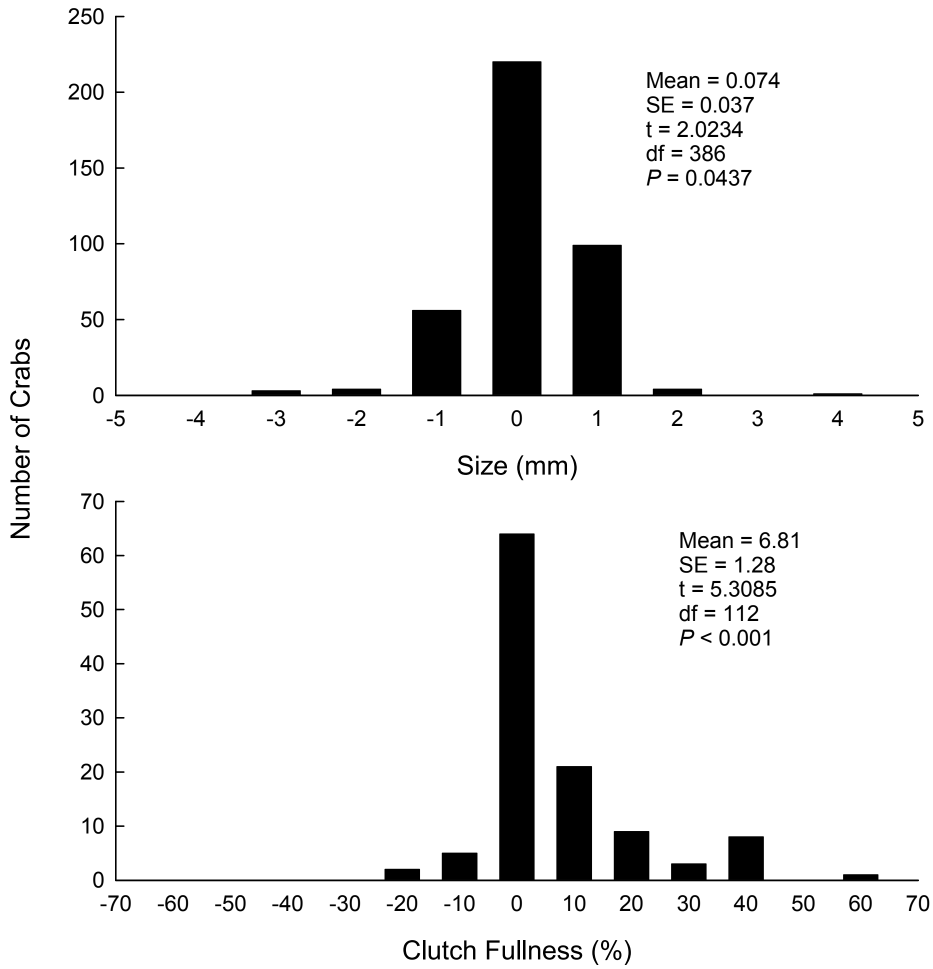

Figure 2. The difference in size and clutch fullness recorded using written and electronic methods. For each type of data, the mean and standard error (SE) are given for the difference between measurements for each crab. In both cases the mean was significantly different from zero (one-sample t-tests).

APPENDIX

Appendix A. Useful Websites

Handspring™ Handheld Computers: <http://handspring.com/> (Accessed: 28 February 2003)

ViewSonic Handheld Computers: <http://viewsonic.com/> (Accessed: 28 February 2003)

Sceptre Handheld Computers: <http://sceptre.com/> (Accessed: 28 February 2003)

DataGet®: <http://www.dataget.com/> (Accessed: 28 February 2003)

HanDBase: <http://www.ddhsoftware.com> (Accessed: 28 February 2003)

Symbol Bar code Scanners: <http://www.symbol.com/> (Accessed: 28 February 2003)

Mitutoyo™ Calipers: <http://www.mitutoyo.com> (Accessed: 28 February 2003)

Fowler Calipers: <http://www.fvfowler.com/> (Accessed: 28 February 2003)

Otter Box: <http://Otterbox.com/> (Accessed: 28 February 2003)