Dredged Disposal Site Biological Characterization

2014-2015 Trawl Study at the Anderson/Ketron Island Disposal Site Pierce County, WA

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ABSTRACT

The Dredged Material Management Program (DMMP) agencies (Corps of Engineers, Environmental Protection Agency, Washington Departments of Ecology and Natural Resources) jointly manage eight open-water disposal sites in Puget Sound, including five nondispersive and three dispersive sites. The Anderson/Ketron Island disposal site is a nondispersive site serving dredging projects in southern Puget Sound. The site was established in 1989 and to date has received approximately 160,000 cubic yards of dredged material. In 2011, the Nisqually Reach Aquatic Reserve was established and includes the Anderson/Ketron Island disposal site within its boundary. The management plan for the reserve includes dredged material disposal as an approved use. However, stakeholders expressed concerns about potential impacts of dredged material disposal on biological resources within the reserve. The present study was designed to address this concern.

In the mid-1980's the multi-agency Puget Sound Dredged Disposal Analysis (PSDDA) Program (now called the DMMP) was delegated with the task of establishing a comprehensive dredged material management program for Puget Sound, including development of dredged material evaluation procedures; establishment of multiuser open-water disposal sites; and creation of management plans for the sites, including monitoring procedures. Zones of Siting Feasibility (ZSFs) were selected based on 19 factors, including proximity to areas with dredging activities; physical parameters such as currents and bathymetry; human uses; and biological resources. Additional studies were conducted within the most promising ZSFs, including demersal resource investigations. Based on the findings of these studies, the PSDDA Disposal Site Work Group selected three dispersive and five nondispersive sites, including the Anderson/Ketron Island nondispersive site.

The focus of the current study was to replicate, in part, the 1987 demersal resource evaluation of the Anderson/Ketron Island disposal site and surrounding area utilizing a Plumb-staff beam trawl comparable to the one used in the initial investigations (Dinnel et al. 1987a,b,c,d,e; Dinnel et al. 1988). To maximize comparability between the two studies, seasonal trawling intervals occurred in July, October, February and May, consistent with the 1987 siting study intervals. The study was designed to compare the existing epibenthic invertebrate community between off-site and on-site stations, and to see if noticeable changes have occurred in the existing benthic community relative to the 1987 study.

Both studies focused on "invertebrate species of actual or potential commercial and sport concern," notably Dungeness crab, "rock crab" (red rock crab and graceful rock crab combined), Pandalid shrimp, and sea cucumbers, but also provided information on sea star density. For the study area as a whole, Dungeness crab (*Cancer magister*) were twice as abundant in the 2014-2015 resource assessment than in the 1987 siting study, though still not prevalent. Dungeness crab were scarce on-site. "Rock crab" were substantially more abundant in 2014-2015, with graceful rock crab (*Cancer gracilis)* being widespread and prolific. Red rock crab (*Cancer productus*) were less common than *C. gracilis* throughout the area and scarce on-site. Pandalid shrimp, collectively, were far more abundant in 2014-2015, most notably northeast of the Nisqually Delta, near Oro Bay, and west of the disposal site. However, similar to 1987, recreationally-harvested shrimp such as spot prawns (*Pandalus platyceros*) were scarce on-site. Pandalid shrimp collected from on-site stations were primarily pink shrimp (*Pandalus jordani* and *P. eous*). The commercially harvestable California sea cucumber (*Parastichopus californicus*) was half as abundant in 2014-2015 compared to 1987 and was scarce on-site. Sea stars were slightly more abundant in 2014-2015, but were similarly distributed in both studies. On-site abundance of sea stars was low in both studies. In addition to the "invertebrate species of actual or potential commercial and sport concern," more than 50 other invertebrate species and nearly 50 species of fish were captured during the course of the 2014-2015 study, indicating the diversity of habitats and species occurring within the study area.

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Appendix H. Herrera and NewFields 2015b (electronic only). *Final October 2014 Post-Cruise Summary Report – 2014-15 Trawl Study at the Anderson/Ketron Island Disposal Site, Pierce County, WA*. September 1, 2015. 51 pp., plus appendices

Appendix I. Herrera and NewFields 2015c (electronic only). *Final February 2015 Post-Cruise Summary Report – 2014-15 Trawl Study at the Anderson/Ketron Island Disposal Site, Pierce County, WA*. September 1, 2015. 59 pp., plus appendices

Appendix J. Herrera and NewFields 2015d (electronic only). *Final May 2015 Post-Cruise Summary Report – 2014-15 Trawl Study at the Anderson/Ketron Island Disposal Site, Pierce County, WA*. September 1, 2015. 59 pp., plus appendices

Acronyms and Abbreviations

CL	Carapace Length
cm	centimeter
CW	Carapace Width
DGPS	Differential Global Positioning System
DMMP	Dredged Material Management Program
ft	Foot/Feet
ha	hectare
km	kilometers
km/h	kilometers/hour
m	meter
MLLW	Mean Lower Low Water
mm	millimeter
PSDDA	Puget Sound Dredged Disposal Analysis
R/V	Research Vessel
TL	Total Length
USACE	U.S. Army Corps of Engineers
WDFW	Washington Department of Fish and Wildlife
ZSF	Zone of Siting Feasibility

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1.0 INTRODUCTION

DMMP Program. In the mid-1980s the multi-agency Puget Sound Dredged Disposal Analysis (PSDDA) program was formed with the task of establishing and managing open-water dredged material disposal sites in Puget Sound, which required identifying locations suitable for disposal sites, developing dredged material evaluation procedures, establishing disposal site management plans, and implementing a monitoring program for the disposal sites. The PSDDA agencies included the Corps of Engineers, Environmental Protection Agency, Washington Department of Ecology and Washington Department of Natural Resources.

In the 1990s the PSDDA program was expanded to include dredged material management in Grays Harbor, Willapa Bay and the Columbia River. With that expansion, the multi-agency program became known as the Dredged Material Management Program (DMMP). The DMMP agencies jointly manage eight disposal sites in Puget Sound, and work together to determine the suitability of dredged material for in-water placement. The Department of Natural Resources is the lead agency for conducting chemical and biological monitoring at the non-dispersive sites and the Corps of Engineers is the lead agency for conducting physical monitoring at both dispersive and non-dispersive sites.

Site Selection in Puget Sound. The PSDDA Disposal Site Work Group (DSWG) was assigned the responsibility of selecting unconfined, open-water disposal sites in Puget Sound that met strict criteria. Selection criteria were based on 19 factors, including proximity to areas with dredging activities; physical parameters such as currents and bathymetry; human uses, including fish and shellfish harvest areas; and biological resources such as threatened and endangered species and habitat types. Initially, DSWG identified Zones of Siting Feasibility (ZSF) in areas of Puget Sound that had the potential to meet the siting criteria. Additional studies were conducted in the most promising ZSFs, including sediment depositional analysis, bathymetric surveys, hydrodynamic modeling, and trawl investigations. Based on study findings, DSWG ultimately selected five non-dispersive and three dispersive disposal sites, distributed throughout Puget Sound.

In southern Puget Sound, three ZSFs were identified in the Nisqually delta area. ZSF 1, between McNeil Island and Steilacoom, was eliminated following a review of existing information. ZSF 2 was located between Anderson Island and Ketron Island. ZSF 3 was located at the south end of Drayton Passage, between Devils Head and Treble Point. Field investigations, including a demersal resource trawl study, were conducted at these latter two ZSFs. The Anderson/Ketron Island ZSF was selected and a nondispersive disposal site established in a deep trough between the islands (Figure 1).

The trawl study that supported selection of the Anderson/Ketron Island disposal site was conducted in 1987 and focused on "invertebrate species of actual or potential commercial and sport concern," notably Dungeness crab, "rock crab" (red rock crab and graceful rock crab combined), Pandalid shrimp, and sea cucumbers, but also provided information on sea star density. Washington Department of Fisheries criteria were utilized during the PSDDA study as indicators of commercially viable densities of crab and shrimp. Disposal of dredged material in an area with a Dungeness crab density of 100 crabs/hectare[1] or less was considered to have a minimal impact on the potential for commercial or recreational harvesting of this species (PSDDA, 1989). Similarly, densities of less than 250 Pandalid shrimp/hectare were considered to be of minimal importance for a potential fishery (David Kendall, pers. comm. 2014).

Monitoring. Since establishment of the Puget Sound disposal sites in the late 1980s, more than 30 post-disposal monitoring events or special studies have been conducted. At the Anderson/Ketron Island

[1] One hectare is equal to 10,000 square meters, or approximately 2.5 acres.

disposal site, these have included a full monitoring event in 2005, a dioxin/furan survey in 2008, a multibeam bathymetric survey in 2014, and sediment fate and transport modeling in 2014. Results from monitoring events and studies indicate that the Anderson/Ketron Island disposal site is functioning as intended and the DMMP dredged material evaluation procedures are protecting biological resources at the site. Figure 2 – taken from the 2005 monitoring report – shows the disposal mound after a total of 32,826 cubic yards of dredged material had been placed at the site. Another 107,717 cubic yards were placed at the site in 2007. Since 2007, only 16,672 cubic yards have been placed at the site, the most recent of which was the disposal of 6,093 cubic yards in January of 2014.

Nisqually Reserve. In 2011, the Department of Natural Resources established the Nisqually Reach Aquatic Reserve, with the purpose of conserving and enhancing critical habitats and species and promoting research, monitoring and education in the area. The reserve completely surrounds Anderson and Ketron Islands, including the location of the Anderson/Ketron Island disposal site (Figure 3). The Reserve designation means that DNR, within its statutory authority, can approve uses that have been demonstrated to be consistent with the reserve's goals, objectives, and management actions. The management plan for the Nisqually Reach Aquatic Reserve includes dredged material disposal at the Anderson-Ketron Island site as an approved use, contingent on the scientific oversight of the DMMP agencies.

Since establishment of the Nisqually Reach Aquatic Reserve, concern has been expressed by some stakeholders that continued use of the site threatens biological resources within the Reserve. It has also been contended that the biological resources at the disposal site have changed significantly since the site was established, such that continued use of the site for dredged material disposal is adversely impacting those on-site resources.

Present Study. To address these concerns, the DMMP agencies committed to replicate the epibenthic portion of the demersal resource evaluation conducted in ZSF 2 during the original PSDDA siting study. The 1987 study showed that the biological resources in the deep trough between Anderson Island and Ketron Island were relatively sparse compared to more productive habitat in shallower water adjacent to the site and within the Nisqually Delta and Oro Bay. This included invertebrate species of potential commercial and sport interest. By replicating the 1987 study, the disposal site and vicinity could be evaluated for changes in the status of biological resources.

The present study, conducted in 2014-2015, used a plumb-staff beam trawl comparable to the one used in the initial investigations (Dinnel et al. 1987a,b,c,d,e; Dinnel et al. 1988). To maximize comparability between the two studies, seasonal trawling intervals occurred in July, October, February and May, consistent with the 1987 siting study intervals. The quarterly deployment of the beam trawl was considered the most appropriate mechanism to evaluate the benthic crab, Pandalid shrimp, and other demersal resources in the vicinity of the Anderson/Ketron Island site. The study was designed to compare the existing epibenthic invertebrate community between off-site and on-site stations, and to determine whether any important changes had occurred in the existing benthic community relative to the 1987 study.

This trawl study report provides a summary of the quarterly invertebrate resource catch results of the 2014-2015 beam trawl survey conducted at the Anderson/Ketron Island disposal site and nearby Nisqually Reach. In addition, this report compares the 2014-2015 data to the original 1987 quarterly trawl surveys and compares data from on-site stations to off-site stations. Lastly, the report compares on-site Dungeness crab and Pandalid shrimp densities to the commercially-viable thresholds used in 1987 and provides an additional qualitative assessment of the commercial viability of various Pandalid shrimp species by WDFW.

Figure 1. Vicinity Map

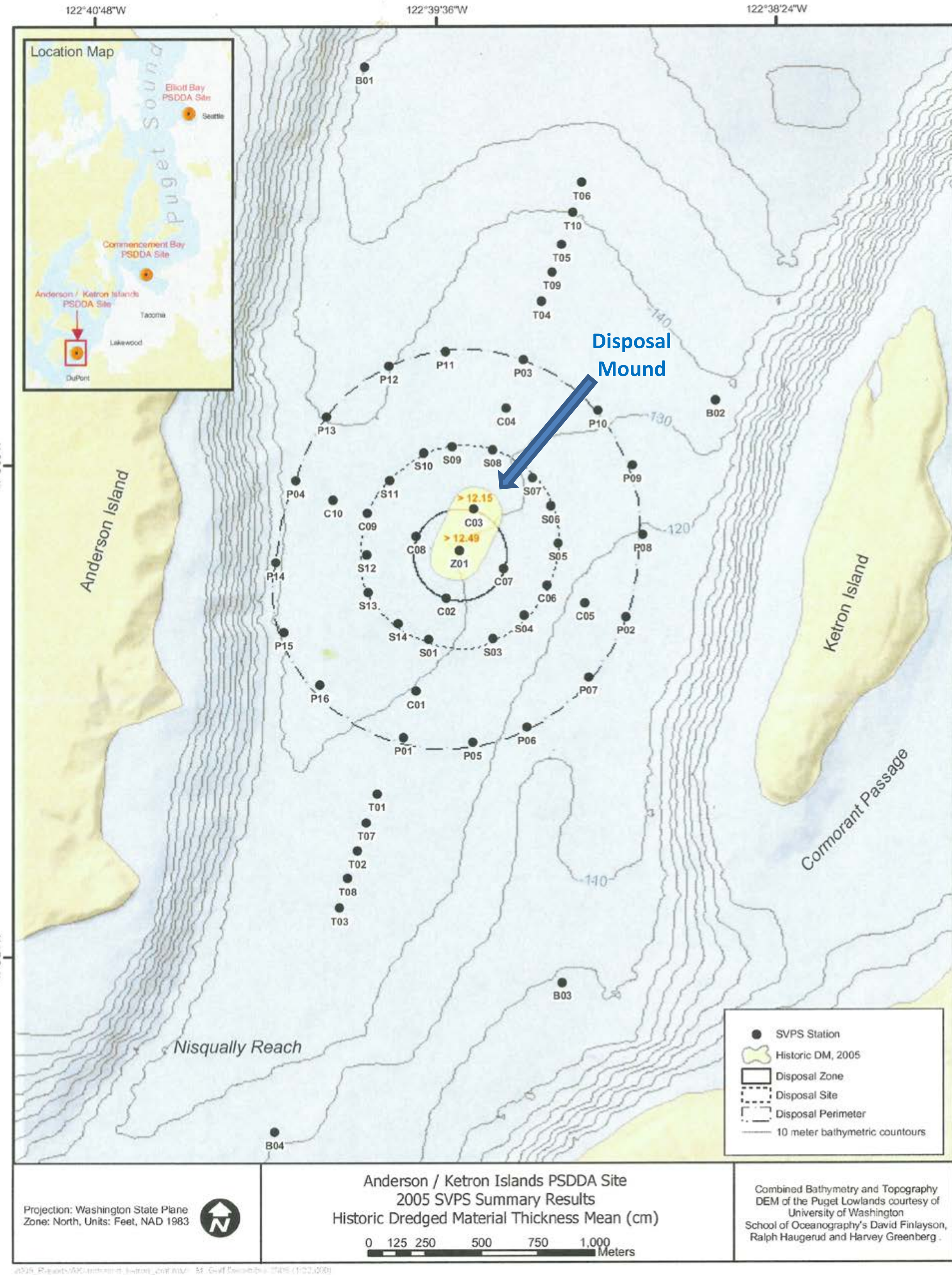


Figure 2. Dredged Material Disposal Mound from 2005 Sediment Profile Imaging Survey at Anderson/Ketron Island Site

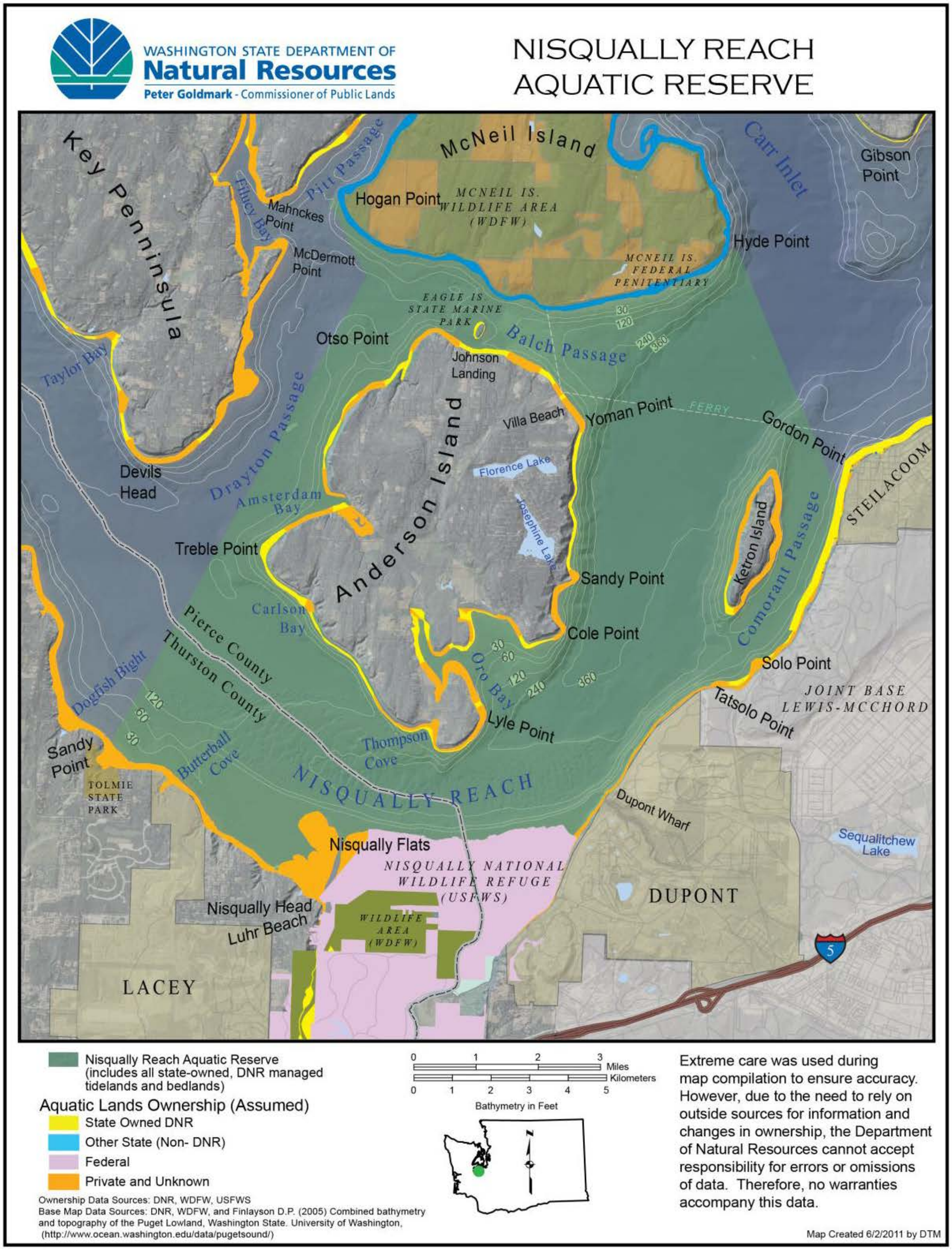


Figure 3. Nisqually Reach Aquatic Reserve

2.0 METHODS

2.1 Trawl Stations

To remain consistent with the original 1987 siting study (Dinnel et al. 1987a,b,c,d,e; Dinnel et al. 1988), the same 30 trawl stations investigated for the siting study were also surveyed quarterly (July and October 2014, and February and May 2015) in 2014-15 using a beam trawl, described in Section 2.3 below. To improve the understanding of the existing benthic community of the disposal site, the 2014-15 investigation added eight sampling stations (EW-1 through EW-5; S-2 through S-4) within the disposal site boundary, or in its immediate vicinity (Figure 4).

In Figure 4, the inner solid circle bounds the "disposal zone", the area within which disposal must occur. That is, the doors on bottom-dump barges are not allowed to open until the barges are completely within the disposal zone. The "disposal site boundary" is the second of the three circles/ellipses in Figure 4, shown as a dashed line. The disposal site was designed such that little, if any, dredged material would spread beyond the disposal site boundary after multiple disposal events. The outer line, termed the "perimeter line", is used during disposal site monitoring to verify that there has been no significant spread of dredged material beyond the disposal site boundary.

The 30 trawl stations that remained the same between the 1987 siting study and the 2014-15 investigation are 'Nisqually D' and those stations beginning with 'T' (for transect) or 'ZSF'. The eight stations added for the 2014-15 investigation are those beginning with 'EW' (for east-west transect) or 'S' (for south transect). With the exception of Station S-4, these additional stations are all within the disposal site boundary. Only one station (ZSF-2.2) from the 1987 study was located within the disposal site boundary. In the remainder of this document, the term "on-site" stations refers to Stations ZSF-2.2, EW-1, EW-2, EW-3, EW-4, EW-5, S-2 and S-3.

2.2 Sampling Vessel

The R/V Kittiwake, a 13-meter research vessel stationed in Seattle, WA, was used for all sampling activities. This is the same research vessel and operator utilized for the 1987 siting study. This vessel is outfitted with beam trawling equipment for fish, shrimp, and benthic community trawling. The vessel is owned and operated by Captain Charles Eaton, a skipper with more than 35 years of experience in Washington waters. The vessel is equipped with winches, davits, a pick and boom, and an extensive open area on the back deck to safely accommodate all sampling gear and operations. The R/V Kittiwake was operated in a manner to maintain a target ground speed of approximately 2.5 kilometers per hour (km/hr) (1.4 knots) during active trawling.

2.3 Beam Trawl

Demersal organisms were sampled using equipment (steel plumb-staff beam trawl) and methods developed by Gunderson and Ellis (1986). These methods were consistent with the 1987 study of invertebrate resources at the site (Dinnel et al. 1988). The beam trawl net consists of a steel beam 3.1 meters (m) long of 3.8 centimeter (cm) conduit, spreading 1 m wings between a 5.1 m footrope and 4.1 m headrope (Figure 5). The effective opening (width) of the net is 2.3 m, with a vertical opening of approximately 1.2 m. The overall length of the net is 7.9 m. The wings, body, and throat of the net are constructed of 9 millimeter (mm) mesh and the cod end is constructed of 4 mm mesh covered with 7.6 cm chafing gear. Floats used on the head rope and wing weights, combined with a tickler chain, ensure optimal vertical spread of the net opening.

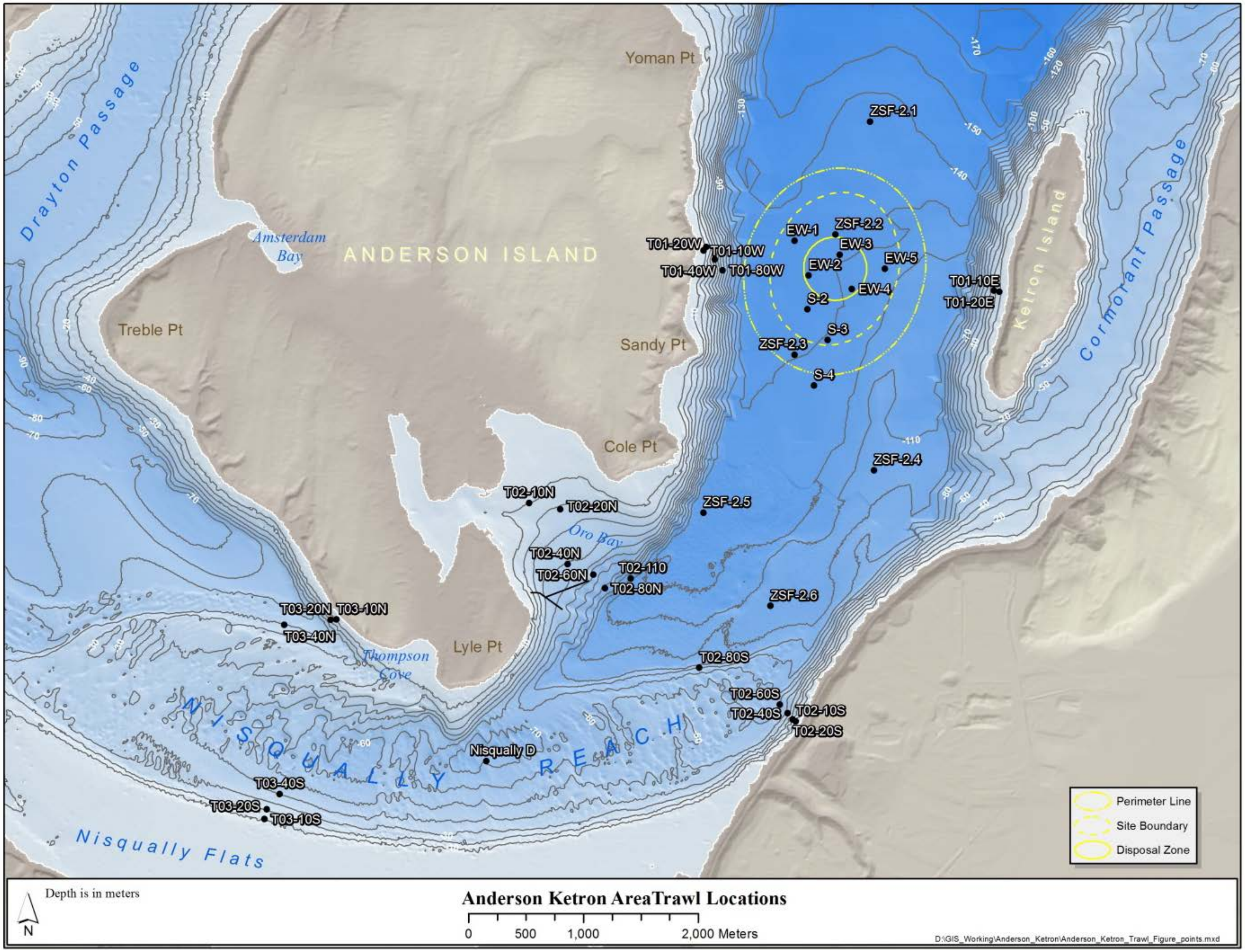


Figure 4. Target Trawl Stations in the Vicinity of the Anderson/Ketron site

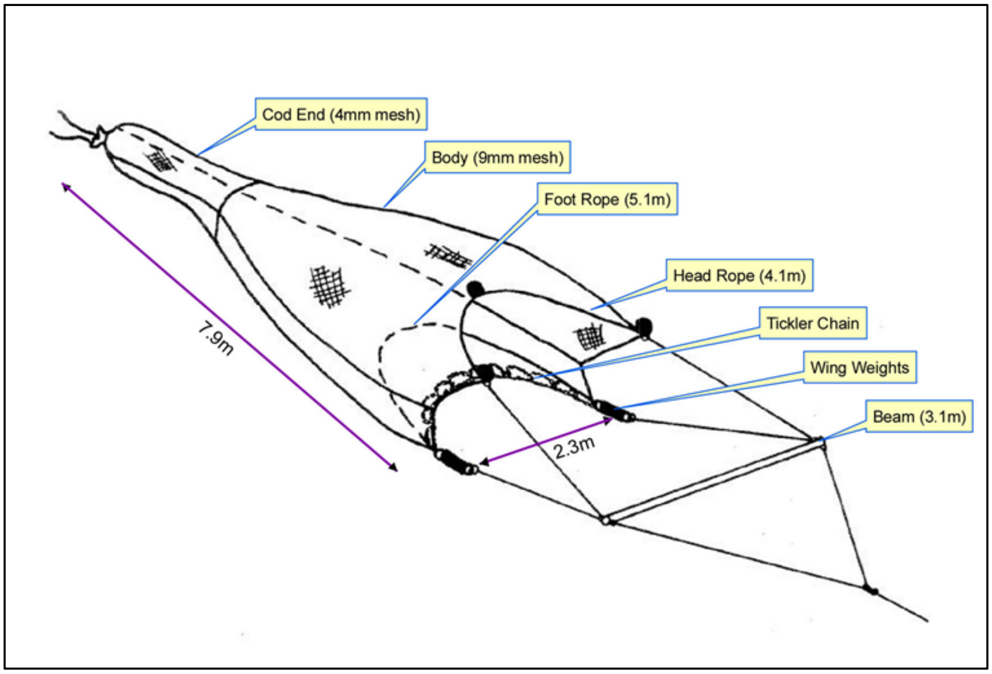


Figure 5. Schematic and Dimensions of the Beam Trawl.

2.4 Trawl Lengths

As stated in Section 2.1, a total of 38 stations were selected for the 2014-2015 trawl study (Figure 4). In the Sampling and Analysis Plan (SAP) for this study (Herrera and NewFields 2014), trawl lengths of 250 feet were planned. However, during the first quarterly sampling event in July 2014, trawl lengths for a number of these stations were shortened to 200 feet due to the large number of organisms captured, or where a large volume of cobble and other debris made recovery of the beam trawl difficult. Large volumes of rock and debris had the potential to increase mortality of the organisms captured during a given tow and to damage the netting. As all organism catch data are converted to density (organisms/hectare) for comparisons between seasons and the original siting data, a relatively small reduction in tow length would have had little or no effect on the integrity of the data collected, while reducing mortality of the captured organisms and the potential for equipment damage. At the center of the Anderson/Ketron Island Disposal Site (EW-3), even the shorter 200-foot tows resulted in the beam trawl bag being too heavy to pull over the stern of the vessel, largely due to shell, rock, and other debris. Although on-site locations were of particular interest for this study, trawl lengths at EW-3 were shortened to 50 feet for the safety of the vessel captain, crew, and scientific team. The quarterly trawl locations, lengths and directions are shown in Appendix A.

2.5 Vessel Navigation and Trawl Position

2.5.1 Replication of 1987 Trawl Stations

In 1987, the location of trawl stations was determined using a combination of radar ranges to permanent features and fathometer readings. When available, stations were located with LORAN C coordinates (Dinnel et al. 1988). Although the general location of each of the trawl stations sampled in 1987 was used in the present study, some minor adjustments in locations and directional headings were warranted. The original trawl stations were meant to provide information about the demersal community along bathymetric contour lines. However, the change in water depth from beginning to end of some of the 1987 trawls was tens of meters. Improvements in bathymetric data and positioning technology allowed more precise tracking of contours in the present study (Herrera and NewFields 2014). The 1987 stations are best thought of as sampling cells, and not as precise trawl lines to be rigorously duplicated. Nor was the goal of the present study to precisely duplicate the exact same trawl line from season to season. Rather, the objective was to take representative samples from within the sampling cells established in 1987.

2.5.2 Methodology Utilized to Estimate Location of Trawl Relative to Target Location

Using the Coast Guard's Nationwide Differential Global Positioning System (DGPS), very accurate towing speeds (to within 0.1 knots) and transect distances (to within 2-5 meters) were obtained. This was important because towing speed and distance were likely the most significant source of sample variability. Accurate measurements of position, tow direction, and length of tow were necessary to correctly locate trawl samples, allow repetitive sampling of transects, and to accurately calculate the area of bottom sampled.

In order to estimate the location of the beam trawl when it began actively sampling the seafloor, a number of factors were required, including water depth, vessel speed, vessel location, and the length of wire out from the vessel winch.

To estimate the trawl location, the vessel operator calculated the position of the trawl behind the vessel. The R/V Kittiwake's DGPS antenna, located directly above the stern of the vessel, allowed for this simple calculation using Pythagorean's theorem for right triangles ($a^2 + b^2 = c^2$) given a = water depth and c = wire out, and solving for b = distance of the trawl behind the boat during a transect (Figure 6).

As the R/V Kittiwake approached the target transect, the vessel was navigated along a heading that was consistent with the proposed beginning and ending points of the trawl. Accounting for vessel speed, tides, currents, winds, and water depth, the vessel operator estimated at what point the beam trawl needed to be deployed in order for it to sink to the bottom while under tow and start sampling at the beginning of the targeted transect.

As the beam trawl was deployed, the time, ship's position, bottom depth, and vessel heading were recorded. As the vessel moved forward, the trawl sank to the bottom while making very slow forward progress (about 1 knot). When the trawl wire reached its designated length for the depth of the station being sampled, the winch was stopped and the actual tow began. The time, depth, heading, and position were recorded.

Once the trawl was on the bottom, the vessel operator entered the DGPS reverse waypoint navigation function to measure the length of the tow. The operator entered the second saved position (the position of the vessel at the beginning of the tow) as a waypoint, but instead of moving toward this point, the vessel moved away from this position. The DGPS then provided a bearing (magnetic or true course) and a constantly increasing range (distance) from the ship's position at the beginning of the tow. When the DGPS indicated that the designated trawl distance was reached, the winch was engaged to terminate the tow and the ending position was "saved" after noting the distance and bearing.

2.5.3 Trawl Position Corrections

Due to strong tides, currents, and wind during active trawling, the vessel can be subject to "crabbing," or moving slightly sideways, as it proceeds along a transect. To account for this, minor trawl position corrections were sometimes necessary.

As discussed in the previous section, the actual beam trawl was not at the stern of the vessel where the DGPS antenna was located, but at a fixed distance behind the vessel (Figure 6). This distance was calculated using Pythagorean's theorem, using the known values for water depth and the length of wire behind the vessel. However, as the vessel heading needed to be adjusted to account for tides, current, and wind during the tow, the beam trawl did not always remain directly behind the vessel. Vessel position was collected three times for each tow; at START SET when the trawl first entered the water, START TOW when the trawl reached the bottom and sampling began, and END when the trawl reached the end of a transect and was retrieved. The following steps helped correct for the beam trawl location:

1. From START TOW position of the vessel, measure back toward START SET the known distance the beam trawl was behind the vessel to estimate the beam trawl position at the start of the tow.
2. From the beam trawl position at the start of the tow, draw a line to the vessel position at the end of the tow. This provided the track of the beam trawl.
3. Along the track of the beam trawl, measure this trawl distance to the end of the tow. The line between the beam trawl position at the start of the tow and the beam trawl position at the end of the tow was the corrected path of the beam trawl.

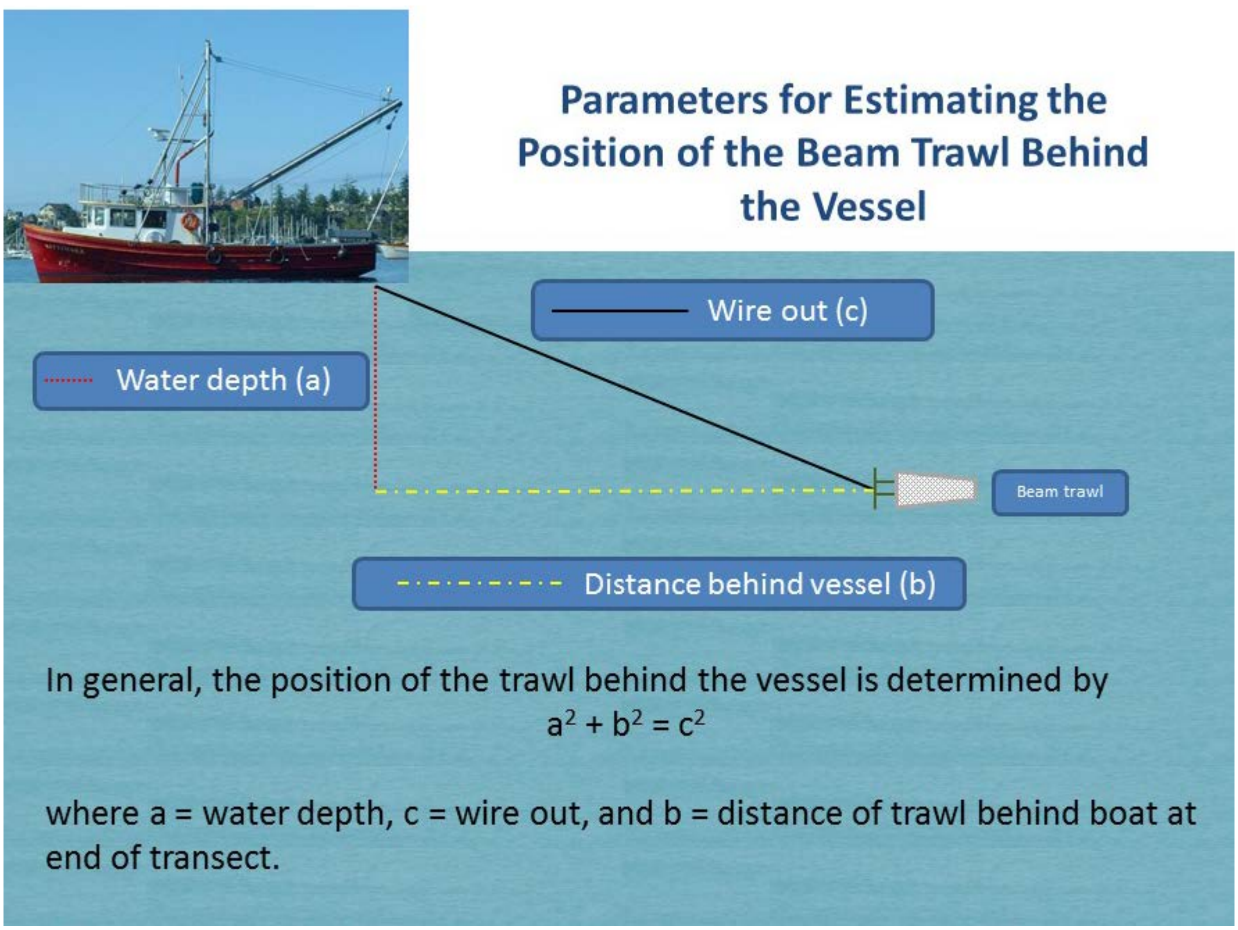


Figure 6. Parameters for Estimating the Position of the Beam Trawl behind the Vessel.

2.6 Biological Information Collected

Following each trawl, the net was retrieved and the captured organisms were shaken toward the cod end of the net. The cod end was then positioned over, and emptied into, large plastic tubs filled with ambient site water. The fish and invertebrates were sorted into species groups, identified, and enumerated. Fish were measured for total length (TL) to the nearest millimeter for the first 30 individuals of a given fish species. Total length refers to the length of a fish measured from the tip of the snout to the tip of the longer lobe of the caudal fin (tail). Metrics for each *Cancer* and *Chionoecetes* crab captured included determining the carapace width (CW) measured to the nearest millimeter, sex (male or female), and a two-category shell strength determination (soft or hard shelled). Metrics for the first 60 individuals of a given Pandalid species caught in a trawl included carapace length (CL) measured to nearest millimeter. Other demersal invertebrates were identified to species (when possible) and counted.

2.7 Data Analyses

Converting the catch data for each transect from number of organisms captured to density of organisms allowed comparison of organism abundance between sampling areas. It was also essential for the comparison of 2014-2015 data to the 1987 data, which were presented in the number of organisms per hectare. Beam trawl catches of demersal organisms were converted to densities based on calculations of the area swept by the beam trawl. To compensate for variability in trawl tow distances, all catch data were converted into catch/hectare (ha, which equals 10,000 square meters or approximately 2.5 acres) based on an effective beam trawl fishing width of 2.3 m (7.5 ft) and the estimated trawl distance for "net on bottom," as described in Section 2.5 and using the following formula:

$$\text{Organisms/ha} = \frac{(\text{No. of organisms caught})}{(\text{trawl distance in m}) \times (\text{trawl width} = 2.3\text{ m})} \times \frac{(10{,}000\text{m}^2)}{1\text{ ha}}$$

3.0 Results and Comparison to 1987 Siting Study

The general description of the Nisqually region has not changed since the 1987 siting investigation (Dinnel et al. 1988), with the benthic habitats supporting an extremely rich and diverse community of demersal organisms. Benthic habitat type in Puget Sound is largely a function of location and environmental conditions. In the Nisqually Reach the center channel current is north prevailing. However, nearshore currents form countercurrent eddies along Anderson Island, Ketron Island, and the eastern shoreline of the Nisqually Reach (Burch 2009). The strong nearshore currents have created benthic habitat that includes coarse sand, cobble, and rocks.

Directly seaward (north) of the Nisqually Delta, the study team observed that the benthic environment was comprised of sandy sediment interspersed with woody debris (Herrera and NewFields 2015a, b, c, d). Deep-water habitats (excluding the dredged material disposal site) were comprised of finer grained sediments and mud. These deeper areas also included a large amount of wood, leaf and fircone debris from nearby terrestrial environments (Herrera and NewFields 2015a, b, c, d). Stations near the center of the dredged material disposal site included abundant shell and woody debris, cobble, large rocks and other anthropogenic debris (Herrera and NewFields 2015a, b, c, d). The difference in habitat composition between on-site stations and other nearby deep-water areas may account for the differences in species captured at these locations.

The following sections present the quarterly survey findings of benthic organisms captured during the 2014-2015 study. Where possible, comparisons between stations, between seasons, between on-site stations and off-site stations, and to the 1987 study are presented. To allow for this comparison, the findings are presented in the following categories: Crab, Pandalid Shrimp, Sea Cucumbers, Sea Stars, and Other Invertebrates.

The quarterly trawling events began in July 2014 and ended in May 2015. However, the figures and discussion in this section are sequenced in accordance with the calendar year, beginning with the February 2015 trawling event and ending with the October 2014 trawling event.

3.1 Crab

The 1987 siting study emphasized "resources of potential fisheries importance" in the analyses (Dinnel et al. 1987a,b,c,d,e, 1988). Therefore, to allow for comparisons to the 1987 siting study, crab results are presented in the same categories as the 1987 study: 1) Dungeness Crab (*Cancer magister*), 2) "Rock Crab", comprised of both red rock crab (*C. productus*) and the graceful *Cancer* crab (*C. gracilis*), and 3) Tanner Crab (*Chionoecetes bairdi*).

3.1.1 Dungeness Crab

2014-2015 Summary

During the 2014-2015 study, Dungeness crabs (*Cancer magister*) were caught in relatively small numbers (Figure 7 and Appendix B). For all 38 stations sampled in 2014-2015, the mean density over all four seasons was 7.6 crab/ha, with the quarterly mean Dungeness crab densities ranging from 0.6 crab/ha in October to 12.5 crab/ha in July (Appendix B). In general, Dungeness crabs were more abundant at the shallower stations in the southern portion of the study area, in the vicinity of Oro Bay, and the Nisqually Reach (Figure 7). With respect to age class, the majority of Dungeness crabs were large mature adults exceeding 120 mm in carapace width (CW) (Appendix C). The majority of these crabs were hard-shelled. Adult female crabs, including some that were gravid, substantially outnumbered adult male crabs (Appendix C., Herrera and NewFields 2015a, b, c, d).

Only two Dungeness crabs were found within the boundary of the Anderson/Ketron disposal site during the study. In May, a single adult hard-shelled female (CW = 140 mm) was found at station S-2 (yielding a mean density of 2.1 crab/ha for all on-site stations) and in July, a single juvenile hard-shelled male (CW = 19 mm) was captured at station EW-4 (again yielding a mean density of 2.1 crab/ha for all on-site stations).

Comparison to 1987 Siting Study

The 1987 siting study investigated potential disposal sites on the west and east side of Anderson Island (Dinnel et al. 1988). The investigation on the east side of Anderson Island, where the disposal site was ultimately established, included 30 survey locations extending from the site south towards the Nisqually Delta. To allow for an unbiased comparison of the 2014-2015 study to the 1987 siting study, a summary comparison of the same 30 stations sampled in 1987 was conducted. The results of the comparison are discussed in the following paragraphs and summarized in Table 1.

In 1987, the mean density at these 30 stations over all four seasons was 3.7 crab/ha, with the quarterly mean Dungeness crab densities ranging from 0.6 crab/ha in October to 8.7 crab/ha in February (Figure 8 and Appendix B). No Dungeness crabs were found at the single on-site station (ZSF 2.2) in any season in 1987. No tabular data for size and sex were found for the 1987 siting study, and while some low-resolution graphs are presented for these parameters in Dinnel et al. 1988, the graphs conflict somewhat with the tabular density data in that report. With that caveat in mind, the graphs indicate that all but one of the Dungeness crabs captured were large mature adults exceeding 120 mm in carapace width (CW). Adult females were more abundant than adult males in February, May and July, comprising approximately 73, 62 and 57 percent of the catch respectively. Only males were found in October. Approximately 13 percent of the Dungeness crabs collected in February and May were males near or above legal size (>159 mm). That fraction rose to 29 percent in July and 67 percent in October.

In 2014-2015, the mean density at these same 30 locations over all four seasons was 9.4 crab/ha, with the quarterly mean Dungeness crab densities ranging from 0.7 crab/ha in October to 15.2 crab/ha in July (Figure 7 and Appendix B). Dungeness crabs were, therefore, roughly 2.5 times more abundant in 2014-2015 (9.4 crab/ha) than in 1987 (3.7 crab/ha). As in 1987, the majority of the crabs were large mature adults exceeding 120 mm in CW. Immature crabs (< 120 mm) were collected in February and July only, comprising 28 percent and 5 percent of the population in those two months respectively. The fractions of adult females in February, May and July were 55, 94 and 90 percent respectively. Legal-size males made up 17, 6 and 5 percent of the catch respectively in those same months. Only one Dungeness crab was collected in October, it being an adult male with a CW of 150 mm.

Findings from both studies indicated that Dungeness crabs were detected more frequently in shallower portions of the study area than at deep-water stations (Figures 7 and 8). As with the siting study, no Dungeness crabs were found in any season during the 2014-2015 study at the single on-site station shared by the two studies (ZSF 2.2).

Both the 1987 siting study and the 2014-2015 study indicated that Dungeness crabs were least abundant in October. For male crabs this is likely a function of sport and Treaty commercial harvest during the summer months, which targets large male crabs. For female crabs, it was suggested in the 1987 study that gravid females likely moved into relatively shallow areas during the fall and early winter months (Armstrong et al. 1987, Dinnel et al. 1988). Dungeness crabs were more plentiful in February of 2015 than they were that same month in 1987. However, their distribution was similar, being restricted in both studies to the Nisqually Reach. Differences in May and July were much more apparent, with lower abundance and more limited distribution in 1987 compared to 2014-2015 (Figures 7 and 8).

An interesting observation during both the 1987 siting study and the 2014-2015 study was the relative absence of juvenile Dungeness crab, even at stations near, or adjacent to, the Nisqually Delta. The presence of gravid female Dungeness crabs during both studies indicates that there is some local reproduction and larval production. Possible theories for limited recruitment include insufficient juvenile rearing habitat, failure to retain locally produced larvae, reduced larval and/or juvenile survival, and insufficient male crabs remaining to reliably produce new generations.

3.1.2 "Rock Crab"

2014-2015 Summary

The classification "rock crab" from the 1987 siting study combined red rock crab (*Cancer productus*) and graceful *Cancer* crab (*C. gracilis*). To allow for between-study comparisons, this group classification was retained for the current study. In 2014-2015, "rock crabs" were much more abundant than Dungeness crabs. For all 38 stations sampled, the mean density of "rock crabs" for all four seasons was 386.7 crab/ha, compared to a mean density of 7.6 crab/ha for Dungeness crabs. The 2014-2015 quarterly mean "rock crab" densities ranged from 280.9 crab/ha in February to 530.8 crab/ha in July (Appendix B). "Rock crab" were much more broadly distributed than Dungeness crab, and occurred throughout the study area, including at the disposal site (Figure 9).

Comparison to 1987 Siting Study

To allow for an unbiased comparison of the 2014-2015 study to the 1987 siting study, a summary comparison of the same 30 stations sampled in 1987 was conducted. In 2014-2015, the mean density of "rock crab" at these locations over all four seasons was 448.5 crab/ha, ranging from 304.7 crab/ha in February to 655.8 crab/ha in July. For the 1987 data, the mean density of "rock crab" over all four seasons was substantially lower at 53.7 crab/ha, ranging from 35.6 crab/ha in May to 96.7 crab/ha in October (Figure 10 and Appendix B). Both studies indicated broadly distributed populations (Figures 9 and 10), and indicated no preference towards, or avoidance of, the disposal site.

Species-Specific Evaluation of the 1987 "Rock Crab" Data

No tabular data for species-specific density, size and sex were found for the 1987 siting study. Therefore, it is not possible to make a detailed comparison between the two studies on a species-specific basis. Only one piece of information regarding the relative densities of *C. productus* and *C. gracilis* was provided in Dinnel et al. 1988, which stated, "In general, *C. gracilis* outnumbered *C. productus* by roughly 10-fold in the catches." Low-resolution graphs were also provided in Dinnel et al. 1988, which summarized data from the wider Nisqually area, including both ZSF 2 and ZSF 3. The graphs provided the following information regarding red rock crabs. For *C. productus*, adult females outnumbered adult males by approximately a 2:1 ratio in February, May and July. Adult males were far more numerous than adult females in October. Very few immature *C. productus* were captured in February and May, with the number rising to approximately 20 percent of the catch in July and 60 percent in October. Adult males near or above legal size (127 mm) represented about 24 percent of the red rock crab catch in February. In May, July and October legal males made up approximately 18, 16 and 12 percent of the red rock crab population respectively. Similar graphics are available for *C. gracilis*. However, as this is not a harvestable species, such details are of less importance in making comparisons to the present study.

Species-Specific Evaluation of the 2014-2015 "Rock Crab" Data

The relative abundance of *Cancer productus* and *C. gracilis* in 2014-2015 is illustrated in Figures 11-14, which display the density of each species at each of the trawl stations on a quarterly basis. Red rock crab (*C. productus*) typically occurred at low abundances, accounting for approximately 15% of the total "rock crab" abundance, averaged over all stations and seasons. Abundance of *C. productus* was highest in July (Figure 13), which had nearly three times the mean abundance seen in October (Figure 14). However, a single station (T02-60S) – with a density of over 2,000 crabs/ha in July – accounts for much of the difference between these two months. For all 38 stations sampled in 2014-2015, the mean density over all four seasons was 59.6 crab/ha, with the quarterly mean red rock crab densities ranging from 33.7 crab/ha in October to 102.0 crab/ha in July (Table 2 and Appendix B). Size frequency distributions of red rock crab indicated that the majority of both male and female red rock crabs captured were greater than 100 mm in CW (Table 2 and Appendix C). Juvenile crabs (< 100 mm) were collected in all quarters, but comprised only 9 to 11 percent of the population in February, July and October. The fraction of juveniles was much higher in May, accounting for 36 percent of the total red rock crab catch. Legal-size males (>127 mm) ranged from a low of 25 percent in May to a high of 42 percent in October. The proportion of legal-size females (also >127 mm) was lower, ranging from 3 to 11 percent. The majority of adults between 100 and 127 mm in size were female. Although smaller red rock crabs occurred less frequently (likely due to different habitat preferences), the presence of multiple year classes indicates that some local recruitment of red rock crabs does occur.

Within the "rock crab" classification, graceful *Cancer* crabs (*C. gracilis*) were relatively abundant in 2014-2015, and showed very little seasonality with respect to abundance (Figures 11-14 and Appendix C). Size frequency distributions of graceful *Cancer* crabs indicate that the majority of both males and females captured ranged from 20-100 mm in CW. Male graceful *Cancer* crabs were only slightly more prevalent than female crabs, and occurred at slightly larger sizes. Juvenile graceful *Cancer* crabs occurred throughout the year, with size frequency distributions representative of multiple year classes (Appendix C), indicating strong local recruitment of graceful *Cancer* crabs. Due to the small size of graceful *Cancer* crabs – mature adults are usually 9 cm (3.5 in) in CW – there is no sport or commercial harvest potentially affecting their abundance.

Within the disposal site boundary, *C. productus* was relatively scarce. No red rock crabs were captured on the site in February (Figure 11); four males of various sizes were collected in May (Figure 12), yielding a mean density of 15 crab/ha for all on-site stations; two adult males were collected in July (Figure 13) (mean on-site density = 8.6 crab/ha); and a single adult female in October (Figure 14) (mean on-site density = 5.4 crab/ha). *C. gracilis* was more abundant, with a mean density of 192 crab/ha at the eight on-site stations in February; 228 crab/ha in May; 64 crab/ha in July; and 102 crab/ha in October. Mean on-site densities of *C. gracilis* were driven largely by the numbers of this species found at a single on-site station, EW-3, which had densities of 1,205; 1,587; 344; and 348 crab/ha in February, May, July and October respectively. EW-3 is located near the center of the disposal site. Debris – including abundant shell hash and a moderate amount of wood – found at this station during the 2014-2015 study may be providing more habitat for *C. gracilis* compared to other on-site stations.

3.1.3 Tanner Crab

Tanner crabs (*Chionoecetes bairdi*) were not captured at any station in any season during the 1987 siting study (Dinnel et al. 1988). Tanner crabs are uncommon in south Puget Sound but, when found, typically occur in deep-water habitats (D. Velasquez, pers. comm. 2014). Tanner crabs were captured during the 2014-2015 investigation during one month only (October), when a total of four crabs were found. The captured Tanner crabs were comprised of three males and one gravid female, all found at deeper on-site stations (EW-2 and EW-4) within the disposal site boundary (Table 3), yielding a mean on-site density of 8.8 crab/ha that month.

Table 1. Dungeness Crab (*C. magister*) Densities, Size and Sex – 1987 vs. 2014-2015

Month	Parameter	1987[a]	2014-2015[a]
February	Density (ind/ha)	8.7	12.5
	% Males > 159 mm CW	13	17
	% Males 120 to 159 mm CW	7	0
	% Females > 120 mm CW	73	55
	% Juveniles (< 120 mm CW)	7	28
May	Density (ind/ha)	3.1	9.1
	% Males > 159 mm CW	13	6
	% Males 120 to 159 mm CW	25	0
	% Females > 120 mm CW	62	94
	% Juveniles (< 120 mm CW)	0	0
July	Density (ind/ha)	2.5	15.2
	% Males > 159 mm CW	29	5
	% Males 120 to 159 mm CW	14	0
	% Females > 120 mm CW	57	90
	% Juveniles (< 120 mm CW)	0	5
October	Density (ind/ha)	0.6	0.7
	% Males > 159 mm CW	67	0
	% Males 120 to 159 mm CW	33	100
	% Females > 120 mm CW	0	0
	% Juveniles (< 120 mm CW)	0	0
All Seasons Combined	Density (ind/ha)	3.7	9.4
	% Males > 159 mm CW	21	9
	% Males 120 to 159 mm CW	15	2
	% Females > 120 mm CW	61	78
	% Juveniles (< 120 mm CW)	3	11

[a] density based on the 30 stations common to both studies

[b] size and sex estimates derived from low-resolution graphs in Dinnel et al. 1988, which included all 53 stations from the 1987 study.

[c] size and sex entries based on all 38 stations from the 2014-2015 study.

CW = carapace width   ha = hectare   ind = individual   mm = millimeter

Table 2. Red Rock Crab (*C. productus*) Densities, Size and Sex – 2014-2015

Month	Parameter	2014-2015[a]
February	Density (ind/ha)	38.5
	% Males > 127 mm CW	35
	% Females > 127 mm CW	4
	% Males 100 to 127 mm CW	1
	% Females 100 to 127 mm CW	51
	% Juveniles (< 100 mm CW)	9
May	Density (ind/ha)	64.2
	% Males > 127 mm CW	25
	% Females > 127 mm CW	12
	% Males 100 to 127 mm CW	4
	% Females 100 to 127 mm CW	23
	% Juveniles (< 100 mm CW)	36
July	Density (ind/ha)	102.0
	% Males > 127 mm CW	32
	% Females > 127 mm CW	3
	% Males 100 to 127 mm CW	23
	% Females 100 to 127 mm CW	34
	% Juveniles (< 100 mm CW)	9
October	Density (ind/ha)	33.7
	% Males > 127 mm CW	42
	% Females > 127 mm CW	11
	% Males 100 to 127 mm CW	7
	% Females 100 to 127 mm CW	29
	% Juveniles (< 100 mm CW)	11
All Seasons Combined	Density (ind/ha)	59.6
	% Males > 127 mm CW	33
	% Females > 127 mm CW	8
	% Males 100 to 127 mm CW	9
	% Females 100 to 127 mm CW	34
	% Juveniles (< 100 mm CW)	16

[a] entries based on all 38 stations from the 2014-2015 study.

CW = carapace width   ha = hectare   ind = individual   mm = millimeter

Table 3. Station, Sex, and Carapace Width for the Four Tanner Crab Caught in October 2014.

Station	Sex	CW (mm)
EW-4	F*	91
EW-2	M	48
EW-2	M	54
EW-2	M	48

* Gravid female

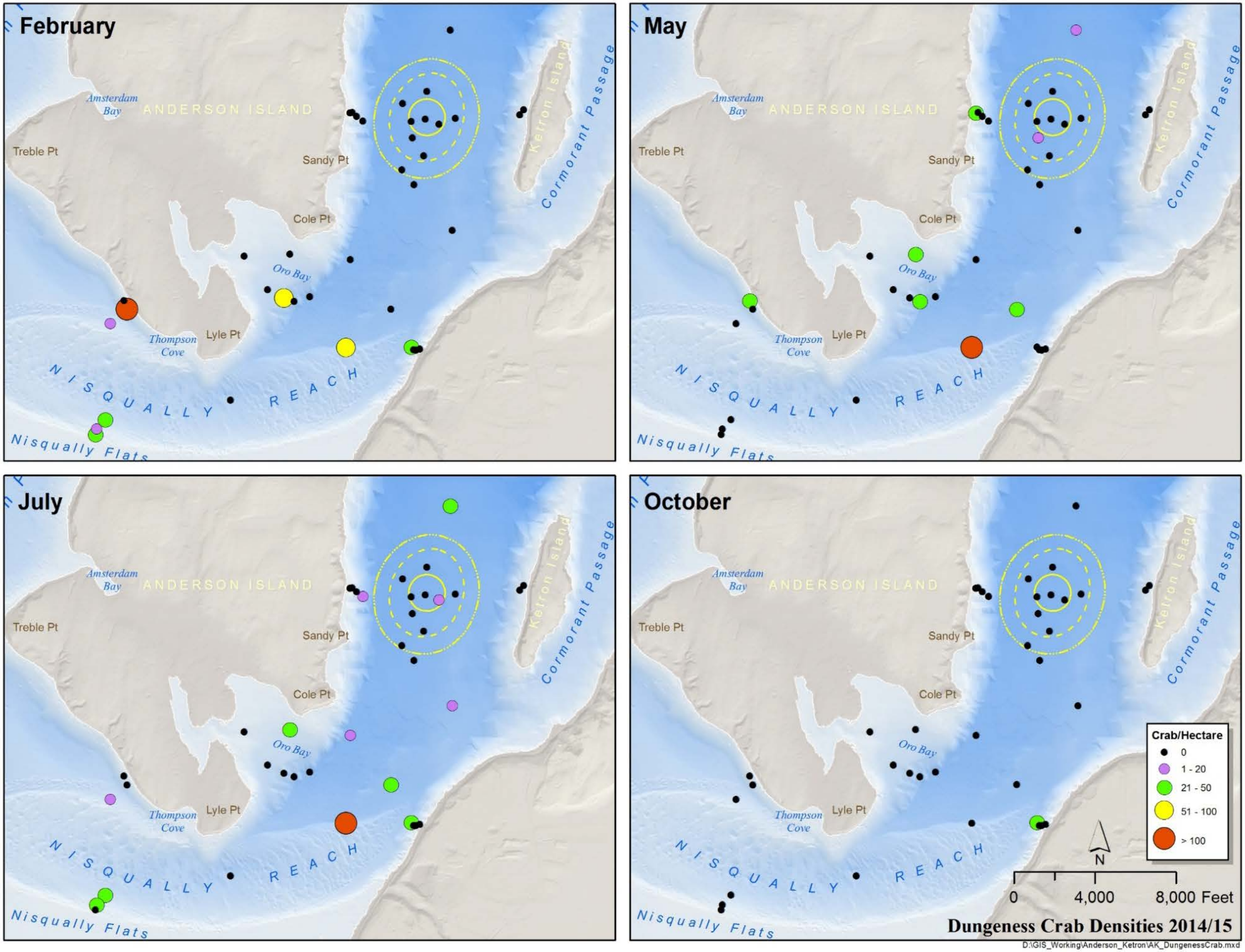


Figure 7. Dungeness Crab Density in the Vicinity of the Anderson/Ketron site in 2014-2015.

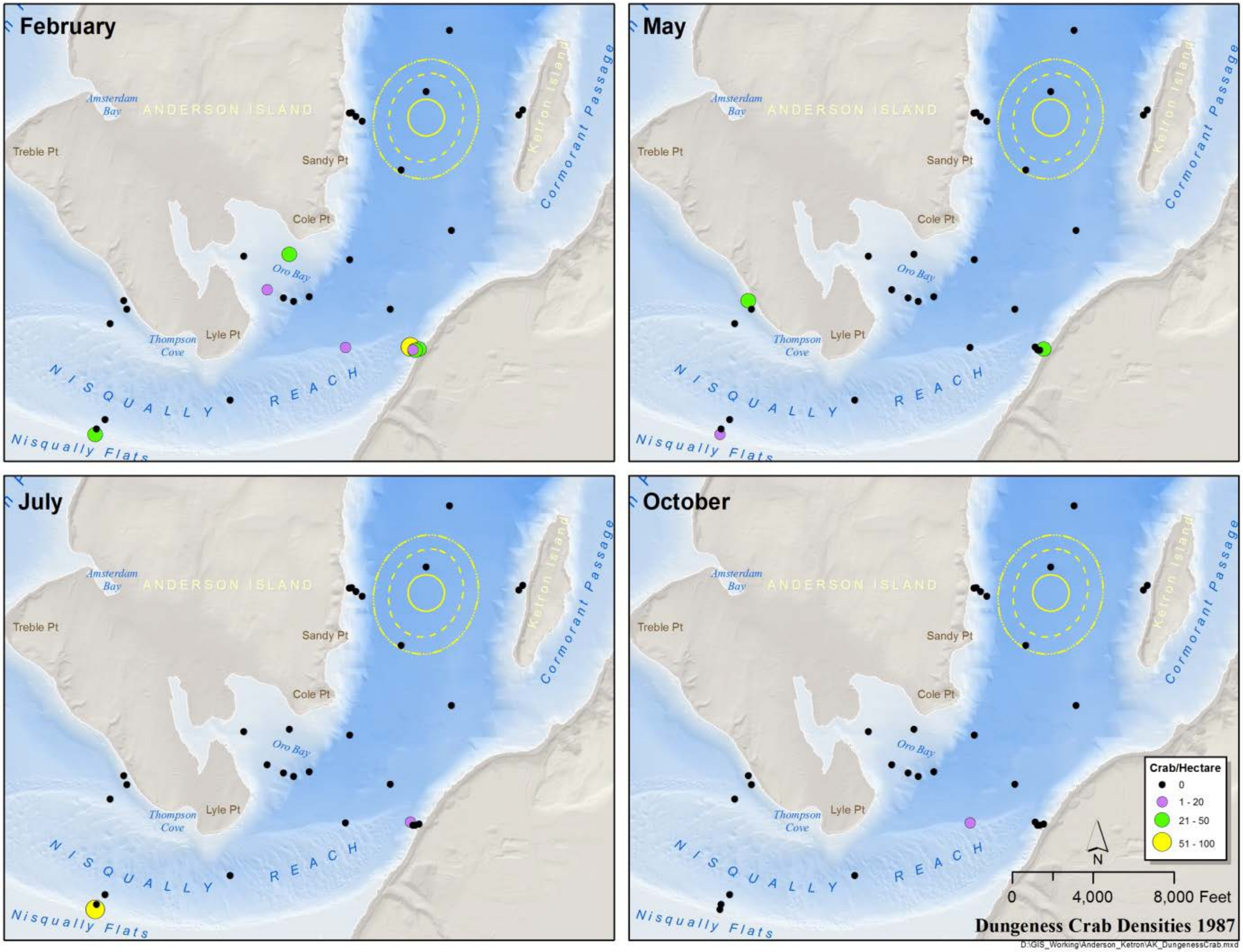


Figure 8. Dungeness Crab Density in the Vicinity of the Anderson/Ketron site in 1987.

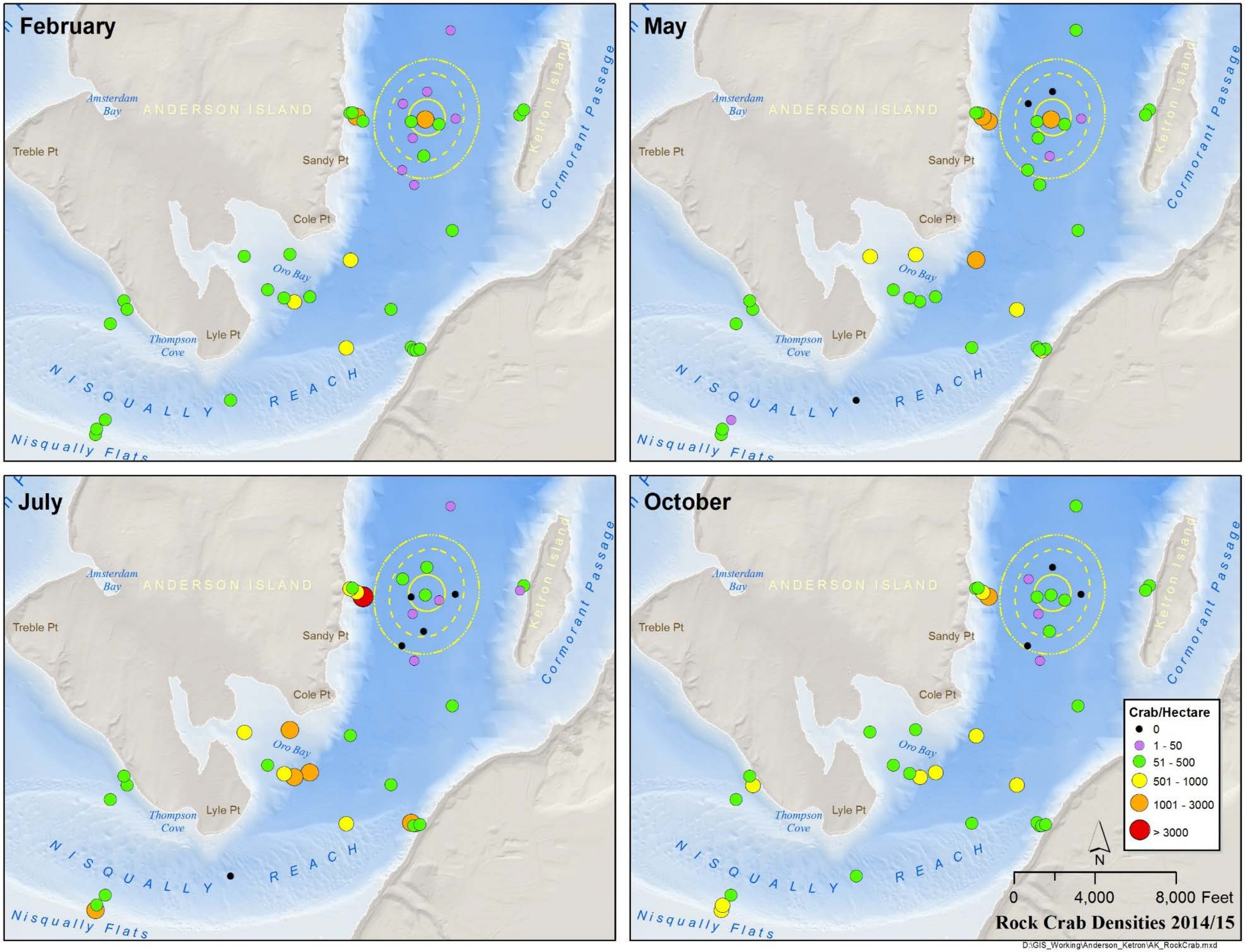


Figure 9. "Rock Crab" Density (*C. productus* and *C. gracilis*) in the Vicinity of the Anderson/Ketron site in 2014-2015.

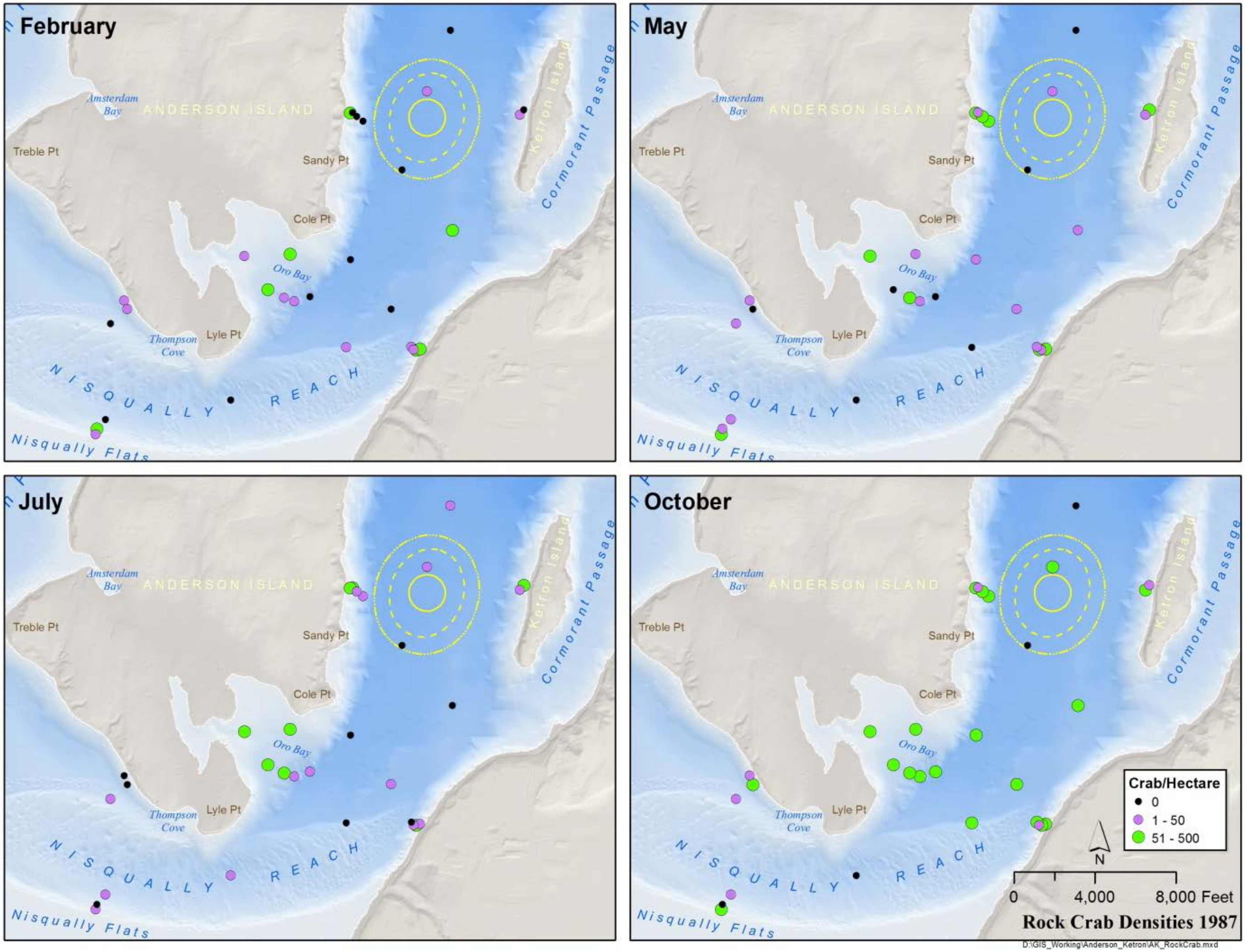


Figure 10. "Rock Crab" Density (*C. productus* and *C. gracilis*) in the Vicinity of the Anderson/Ketron site in 1987.

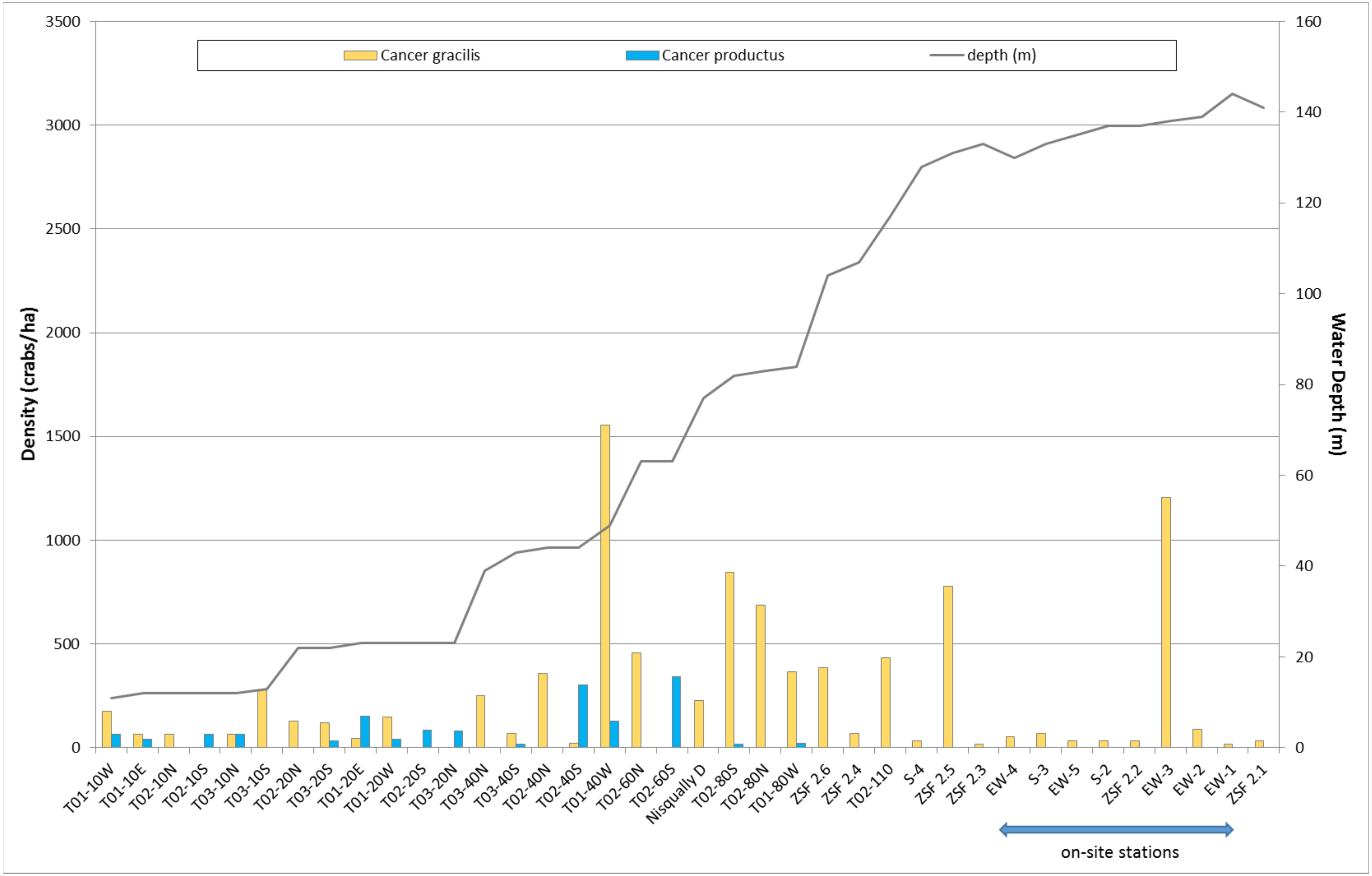


Figure 11. "Rock Crab" Density by Species – February, 2015

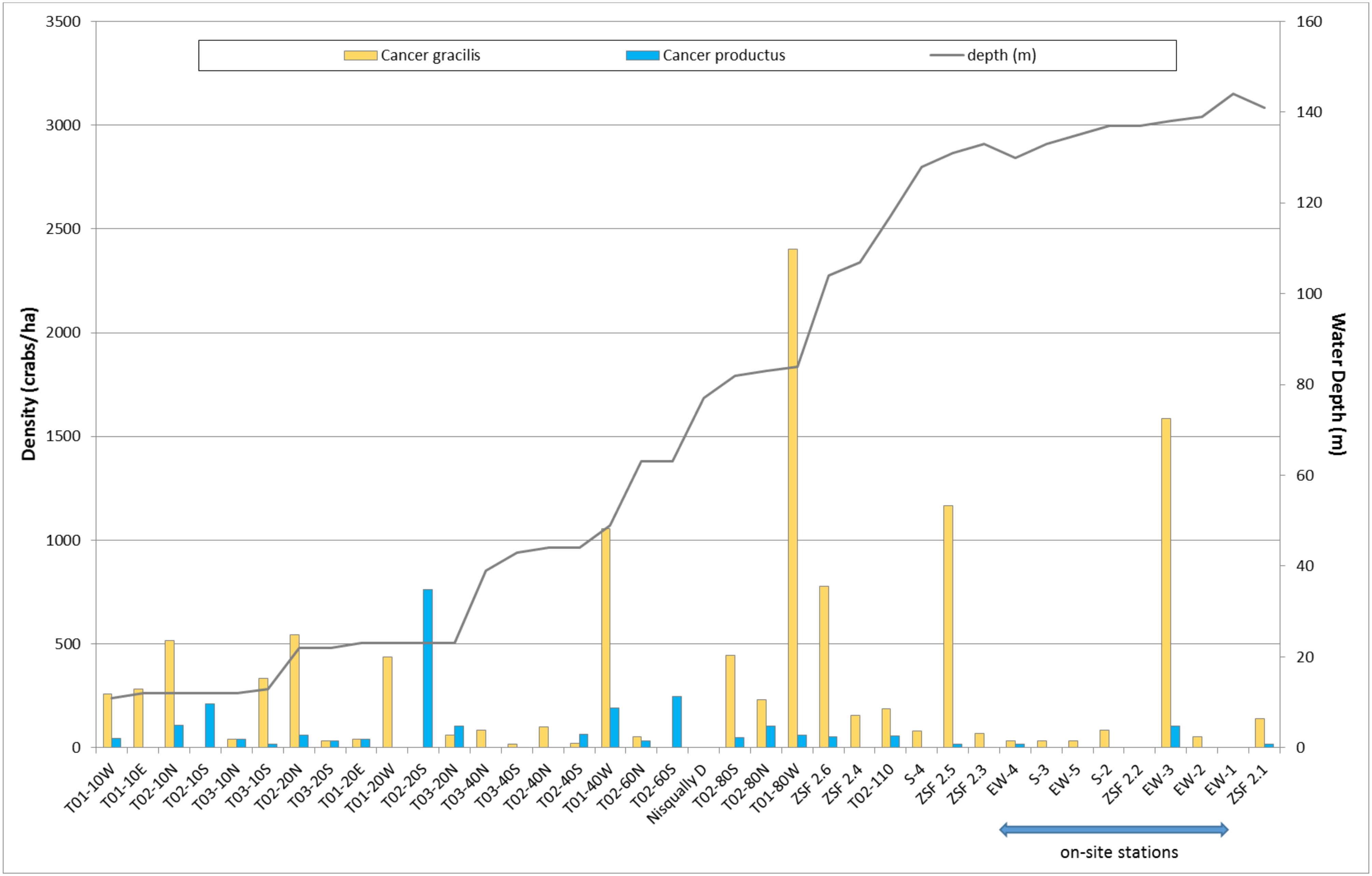


Figure 12. "Rock Crab" Density by Species – May, 2015

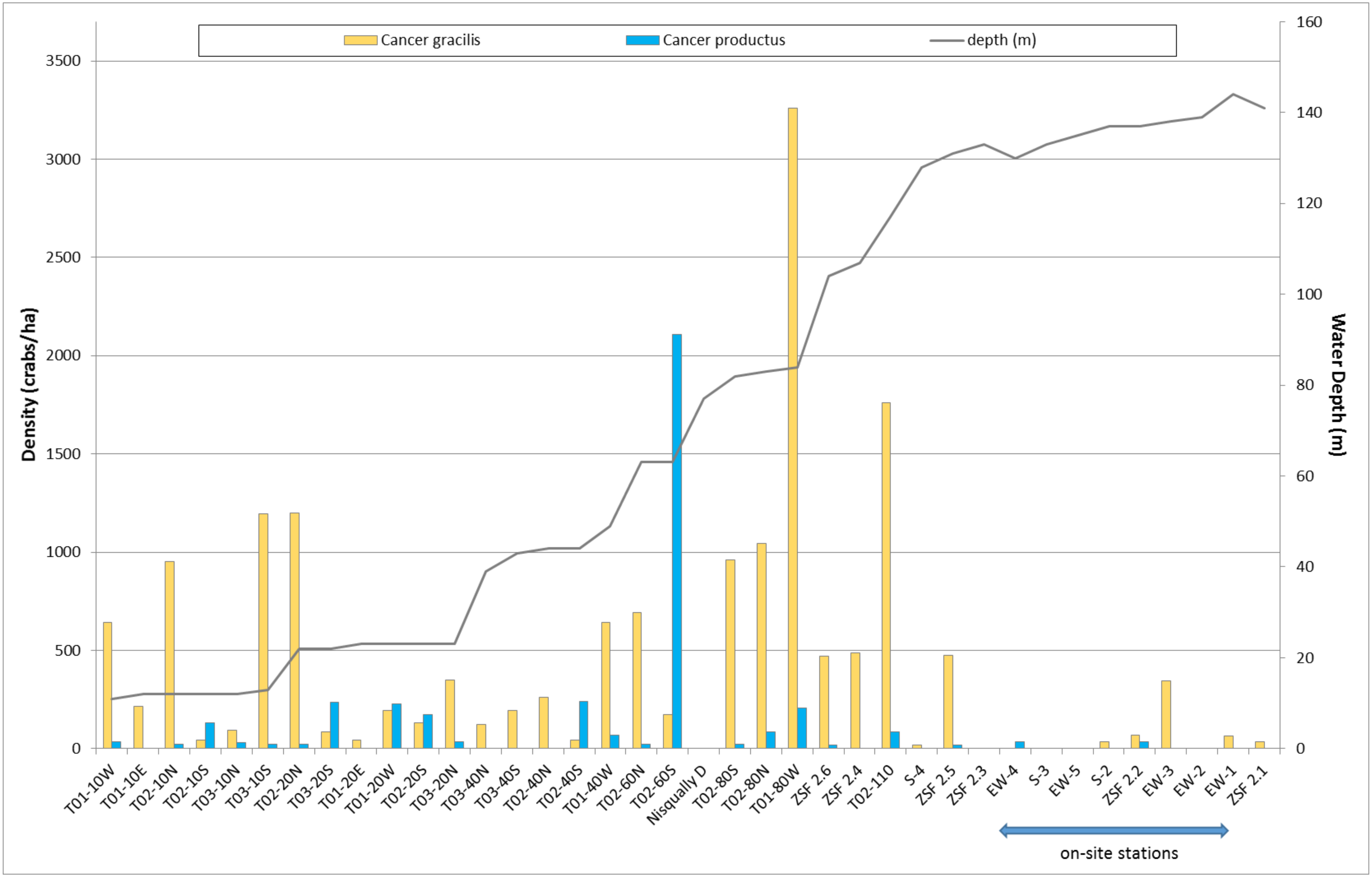


Figure 13. "Rock Crab" Density by Species – July, 2014

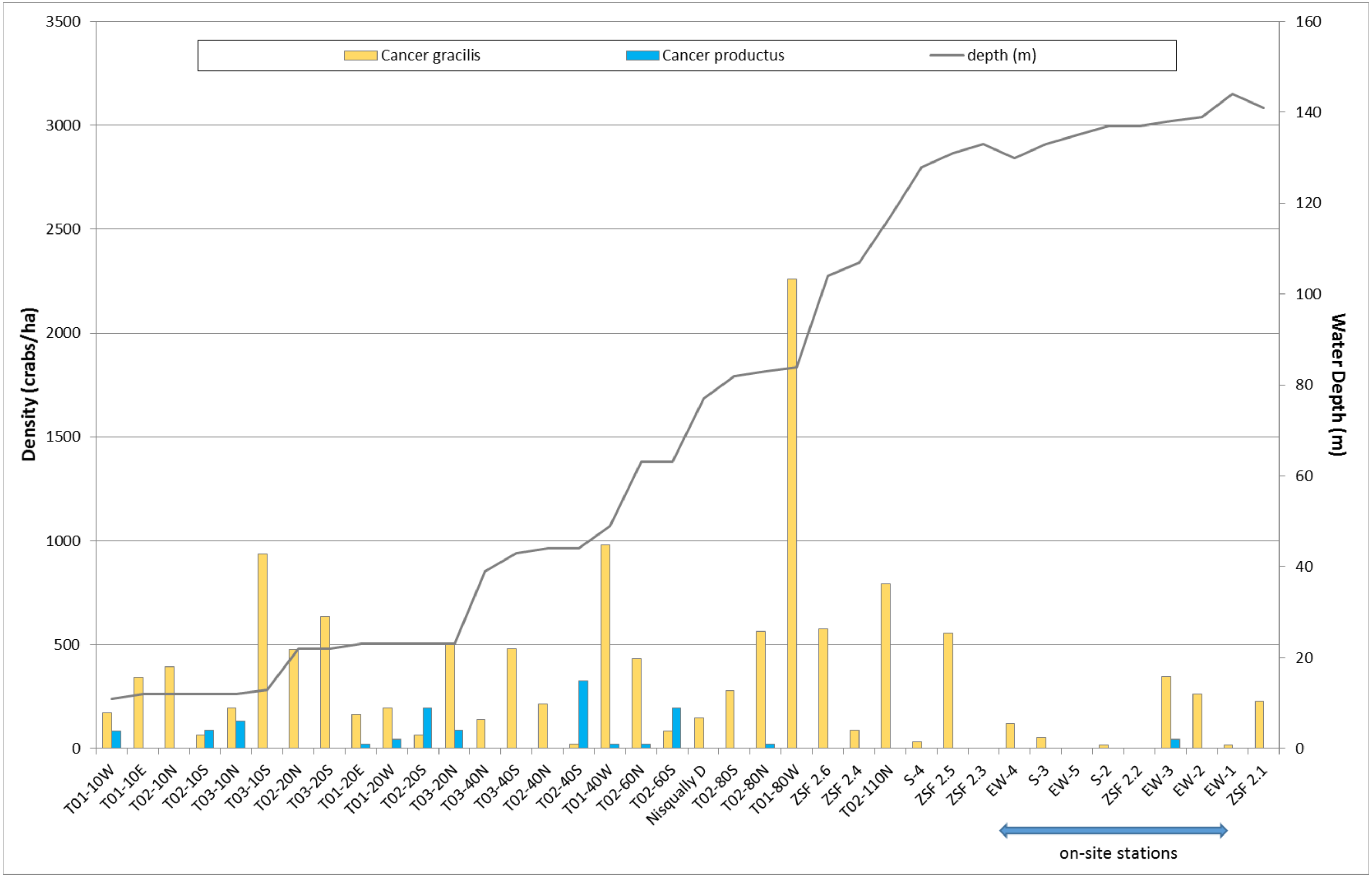


Figure 14. "Rock Crab" Density by Species – October, 2014

3.2 Pandalid Shrimp

2014-2015 Summary

Pandalid shrimp captured for the 2014-2015 study included seven species in the genera *Pandalus* and *Pandalopsis*. To allow for comparison of shrimp distribution and abundance from the 2014-2015 study with the 1987 siting study, data for these two genera were combined.

During the 2014-2015 study, Pandalid shrimp were caught in relatively large numbers (Figure 15 and Appendix B). For all 38 stations sampled in 2014-2015, the mean density of Pandalid shrimp over all four seasons was 4,245 shrimp/ha, with the mean quarterly density ranging from 2,393 shrimp/ha in February to 6,066 shrimp/ha in October (Appendix B). In general, Pandalid shrimp were most abundant at the T02 stations near Oro Bay and northeast of the Nisqually Delta, and at the T01 stations just off the eastern shore of Anderson Island (Figure 15 and Appendix B). They were least abundant at the T03 stations in the vicinity of the Nisqually Flats and northwest of Thompson Cove.

Comparison to 1987 Siting Study

To allow for an unbiased comparison of the 2014-2015 study to the 1987 siting study, a summary comparison of the same 30 stations sampled in 1987 was conducted. In 2014-2015, the mean density of Pandalid shrimp over all four seasons at these 30 stations was 5,155 shrimp/ha, ranging from 2,828 shrimp/ha in May to 7,616 shrimp/ha in October (Appendix B). During the 1987 siting study, Pandalid shrimp were caught in much lower numbers (Figure 16; Appendix B; Dinnel et al. 1988). For all 30 stations sampled in 1987, the mean quarterly density was 86 shrimp/ha, with the quarterly abundance ranging from 11 shrimp/ha in February to 244 shrimp/ha in October (Appendix B). In 2014-2015, Pandalid shrimp exceeded 500 shrimp/ha for 62 of the 120 tows at the 30 stations common to both studies (Figure 15 and Appendix B), whereas in 1987 this only occurred twice (Figure 16 and Appendix B).

Species-Specific Evaluation of the 1987 Pandalid Shrimp Data

No tabular data for species-specific density were found for the 1987 siting study. Therefore, it is not possible to make a detailed comparison between the two studies on a species-specific basis. Low-resolution graphs provided in Dinnel et al. 1988 summarized the combined catches from beam and otter trawls from the wider Nisqually area, including both ZSF 2 and ZSF 3. These graphs provided the following information about the presence and relative abundance of the various Pandalid shrimp species.

Seven species of Pandalids were captured in the study area in 1987, including *Pandalus platyceros, P. danae, P. jordani, P. eous, P. hypsinotus, P. goniurus* and *Pandalopsis dispar*. Very few Pandalids were captured in February and May. *P. eous* had the highest density, with approximately 20 individuals/ha collected in February and perhaps 10 individuals/ha in May. Small numbers of *P. danae* and *P. jordani* were also found in February. These same species were found in May, along with very small numbers of *P. platyceros, P. hypsinotus* and *Pandalopsis dispar*. In July and October, *P. danae* was by far the most abundant of the Pandalids, with an average density throughout the study area of approximately 60 shrimp/ha in July and 180 shrimp/ha in October. Small numbers of *P. jordani, P. eous* and *Pandalopsis dispar* were also collected in both July and October.

Species-Specific Evaluation of the 2014-2015 Pandalid Shrimp Data

The relative abundance of the various species[2] of Pandalid shrimp collected during the 2014-2015 study is illustrated in Figures 17-28. Figures 17-20 display the density of each species at each of the trawl stations on a quarterly basis using a linear density scale. The range covered by the vertical density axis is the same in each of these figures, allowing a direct comparison of abundance results from one season to another. Because some species (e.g. *P. danae*) were so much more abundant than others, the less abundant species have very short bars in these figures, making it difficult to distinguish one species from another. Figures 21-24 address this shortcoming through the use of a log scale for the vertical density axis. When viewing these figures, it is important to keep in mind the visual distortion the use of a log scale introduces. For example, a density of 100 shrimp/ha is displayed by a bar that is only twice as tall as a bar used to represent a density of 10 shrimp/ha. The relative abundance information in Figures 17-24 is provided in a more generalized form in Figures 25-28, which use relatively broad depth classifications to show the variation of Pandalid species composition with depth. In viewing these pie charts, it is important to remember that the size of the pies does not vary, regardless of the actual number of individuals collected within the depth categories. As such, Figures 25-28 should only be used to evaluate the relative density of the Pandalid species at each depth. These figures cannot be used to compare absolute densities between depth classes.

Quarterly size frequency distributions for each of the seven species of Pandalid shrimp captured in 2014-2015 are presented in Appendix D. Only the first 60 individuals of a given shrimp species were measured. As such, the size frequency graphs in Appendix D do not accurately reflect species-specific shrimp abundance and are not meant to be used for that purpose. Species-specific abundance data are found in the catch data appendices of the quarterly Cruise Reports (Herrera and NewFields 2015a, b, c, d). When reviewing shrimp size frequency distributions, it is important to understand shrimp lifecycles. Pandalid shrimp are protandrous hermaphrodites, meaning they initially mature as males and later, as they grow larger, become females, possibly producing two or more broods before dying. Species-specific density and size data from the 2014-2015 study are summarized in the following.

Dock shrimp (*Pandalus danae*): Dock shrimp were the most common of the Pandalid shrimp species captured during the 2014-15 study (Herrera and NewFields 2015a, b, c, d), with large numbers captured at stations along Transect 2 and at the western stations of Transect 1. Quarterly size frequency distributions (Appendix D) indicated a broad population comprised of multiple cohorts.

This species was found most frequently in shallow to mid-depth water, with individuals collected at depths greater than 120 m in October only (Figures 25-28). In February (Figure 21), dock shrimp were collected at 15 of the 38 stations, with densities exceeding 1,000 individuals/ha at six stations and 10,000 individuals/ha at two stations (T02-40S and T02-60S). The distribution of dock shrimp in May (Figure 22) was similar to that in February, with this species being collected at 13 stations. Densities greater than 1,000 shrimp/ha were reported at seven stations in May, six of which were the same stations reporting densities of this magnitude in February; the additional station was T02-10S. Stations T02-40S and T02-60S again had densities greater than 10,000 individuals/ha. The distribution of *P. danae* increased in July (Figure 23) to 18 of 38 stations, with densities greater than 1,000 shrimp/ha reported at nine stations and densities greater than 10,000 individuals/ha at four stations. All four of the highest-density stations were near shore at the southeast end of Transect 2. The widest distribution

[2] Differentiation of the two species of pink shrimp (*Pandalus jordani* and *P. eous*) did not take place in July and was accomplished for only a subset of the October transects. Therefore, these species have been combined for the purposes of illustration and discussion within the report. During the final two seasonal surveys, species differentiation was accomplished for all transects. The ratio of *P. jordani* to *P. eous* was approximately 2.7:1 in February and 3.3:1 in May.

and highest densities of dock shrimp were collected in October (Figure 24), with collections recorded at 26 of 38 stations. October densities exceeded 1,000 shrimp/ha at eleven stations and 10,000 shrimp/ha at four stations, with these latter stations again being the near-shore stations T02-10S, T02-20S, T02-30S and T02-40S. The highest density of any season occurred in October, with over 67,000 dock shrimp/ha reported at station T02-40S.

Despite its abundance and wide distribution, no *P. danae* were captured at any of the eight stations within the Anderson-Ketron disposal site boundary in February, May or July (Figures 21-23). A total of three dock shrimp were captured at the on-site station EW-3 in October (Figure 24), yielding a mean density of 6.6 shrimp/ha for the eight on-site stations that month.

Pink shrimp (*P. jordani* + *P. eous*): Pink shrimp were among the more common of the Pandalid shrimp species captured during the 2014-15 study (Herrera and NewFields 2015a, b, c, d). Quarterly size frequency distributions (Appendix D) of *Pandalus jordani* indicated a population comprised of at least two cohorts, with more adults than juveniles. The quarterly size frequency distributions of *P. eo*us also indicated a population comprised of at least two cohorts, but with more juveniles than adults.

Pink shrimp were restricted to mid-depth and deep-water stations, with none being collected in any season at stations with water depth less than 60 m. In February (Figure 21), pink shrimp were collected at 20 of the 38 stations, with densities exceeding 1,000 individuals/ha at five stations and 10,000 individuals/ha at one station (T02-80N). In May (Figure 22), the densities of pink shrimp increased at the deeper-water stations and fewer were found at mid-depth stations. This shift to deeper water can also clearly be seen when comparing Figures 25 and 26. Pink shrimp were collected at 19 stations in May, with densities greater than 1,000 shrimp/ha reported at 13 stations. None of the stations exceeded a density of 10,000 individuals/ha. The pink shrimp species remained in deeper water in July (Figure 23). Densities exceeded 1,000 shrimp/ha at 11 stations and 10,000 shrimp/ha at a single station (T01-80W). In October, pink shrimp were identified at 20 of 38 stations, with what appears to be a shift back to mid-depth stations. Densities at the deeper-water stations declined, and the density distribution returned to what was seen in February. Density exceeded 1,000 shrimp/ha at six stations. None of the stations exceeded a density of 10,000 shrimp/ha. The highest density of pink shrimp at any station and any season was 29,316 shrimp/ha at station T01-80W in July.

The pink shrimp specie*s* were by far the most commonly captured Pandalids at the eight on-site stations. Densities ranged from a low of 35 individuals/ha in February at station EW-2 to a high of 2,217 individuals/ha in May at this same station. Mean densities – for all on-site stations combined – were 109 individuals/ha in February; 1,353 in May; 1,867 in July; and 235 in October.

Spot prawns (*P. platyceros*)*:* Spot prawns were one of the less common of the Pandalid shrimp species captured during the 2014-15 study (Herrera and NewFields 2015a, b, c, d). However, spot prawns captured were relatively large adult shrimp, with very few under 20 mm in carapace length (CL) (Appendix D). The size frequency distribution suggested that many of the spot prawns captured during this study were mature females, with mature males likely present at lower abundance.

The majority of the spot prawns captured during the 2014-2015 study were at mid-depth to deep-water stations. In February (Figures 21 and 25), spot prawns were collected from three stations, all with water depths between 60 and 120 m. In May (Figures 22 and 26) spot prawns were found at only two stations (T01-80W and ZSF 2.5), both at depths greater than 80 m. In July (Figures 23 and 27), *P. platyceros* were collected at five stations, ranging in depth from 83 to 144 m. October (Figures 24 and 28) was the only month in which spot prawns were found at shallower-water stations. A single spot prawn was captured at each of three stations with water depths less than 50 m. Another individual was collected at

Nisqually-D, which is at a depth of 77 m. Small numbers of spot prawns were also collected in October at three deeper-water stations. Station T01-80W (water depth = 84 m) recorded the highest density of spot prawns, with 2,389 individuals/ha reported in February. T01-80W was also the only station at which spot prawns were collected in every season.

While spot prawns were found mainly at mid-depth to deep-water stations, no spot prawns were captured at any of the eight stations within the Anderson-Ketron disposal site boundary in February, May or October. A total of three spot prawns were captured at the on-site station EW-3 in July, yielding a mean density of 8.2 shrimp/ha for the eight on-site stations that month.

Coonstripe shrimp (*P. hypsinotus*): were also one of the less common species of Pandalids, occurring most frequently in February and May (Herrera and NewFields 2015a, b, c, d). With the exception of October, quarterly size frequency distributions (Appendix D) indicated very consistent bell-shaped curves, with a population comprised of a large successful recruitment class bounded by a few smaller and a few larger individuals. No coonstripe shrimp were captured at any of the eight stations within the Anderson-Ketron disposal site boundary during any of the quarterly trawls.

Sidestripe shrimp (*Pandalopsis dispar*): The sidestripe shrimp was one of the least common of the Pandalid shrimp species captured during the 2014-15 study (Herrera and NewFields 2015a, b, c, d). A distribution could only be determined for May (Appendix D). This distribution indicated a moderate class of shrimp with a mean CL of approximately of 14-15 mm. The numbers of sidestripe shrimp collected during the other seasonal trawls were too small to say anything meaningful about size distributions.

All of the sidestripe shrimp captured during the 2014-2015 study were at stations with water depth greater than 80 m. In February (Figures 21 and 25), a total of 4 sidestripe shrimp were collected from three stations. In May (Figures 22 and 26), sidestripe shrimp were found at only two stations, but the density at one of these stations (ZSF 2.6) was high, at 1,975 shrimp/ha. In July (Figures 23 and 27), a single individual was collected at T02-80N. A total of 4 sidestripe shrimp were collected from three stations in October (Figures 24 and 28).

Over the course of the study, a total of 5 sidestripe shrimp were captured at the eight on-site stations, with two captured in February (yielding a mean of 7.5 shrimp/ha for the on-site stations) and three captured in October (mean density = 6.6 shrimp/ha).

Yellowleg shrimp (*P. tridens*): *P. tridens* was the least common of the Pandalid shrimp species captured during the 2014-15 study (Herrera and NewFields 2015a, b, c, d). This species was found in July only, at a single deep-water station (ZSF 2.1) north of the disposal site. The July distribution (Appendix D) indicated a small number of juvenile shrimp. No yellowleg shrimp were captured at any of the eight stations within the Anderson-Ketron disposal site boundary during any of the quarterly trawls.

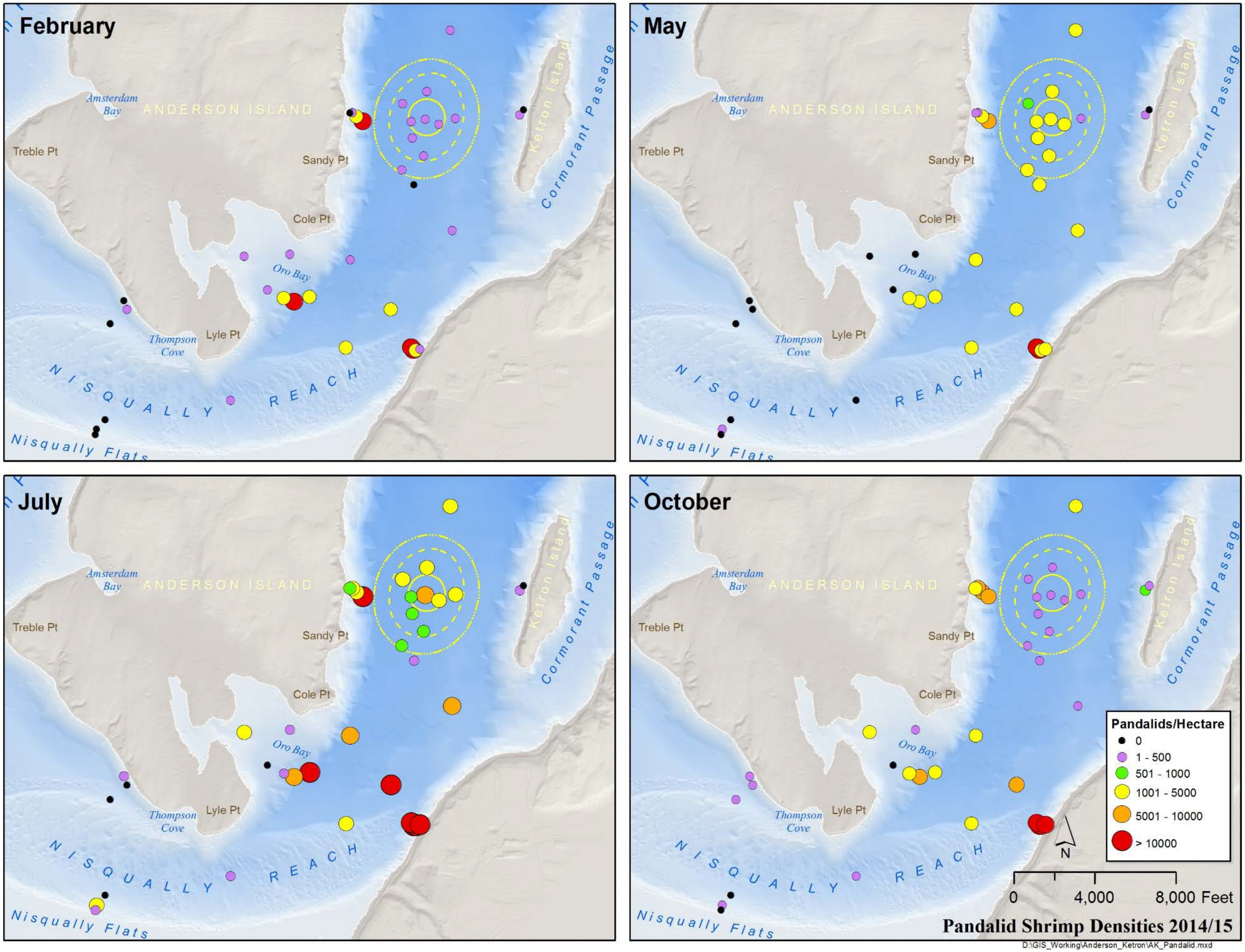


Figure 15. Pandalid Shrimp Density (all species combined) in the Vicinity of the Anderson/Ketron site in 2014-2015.

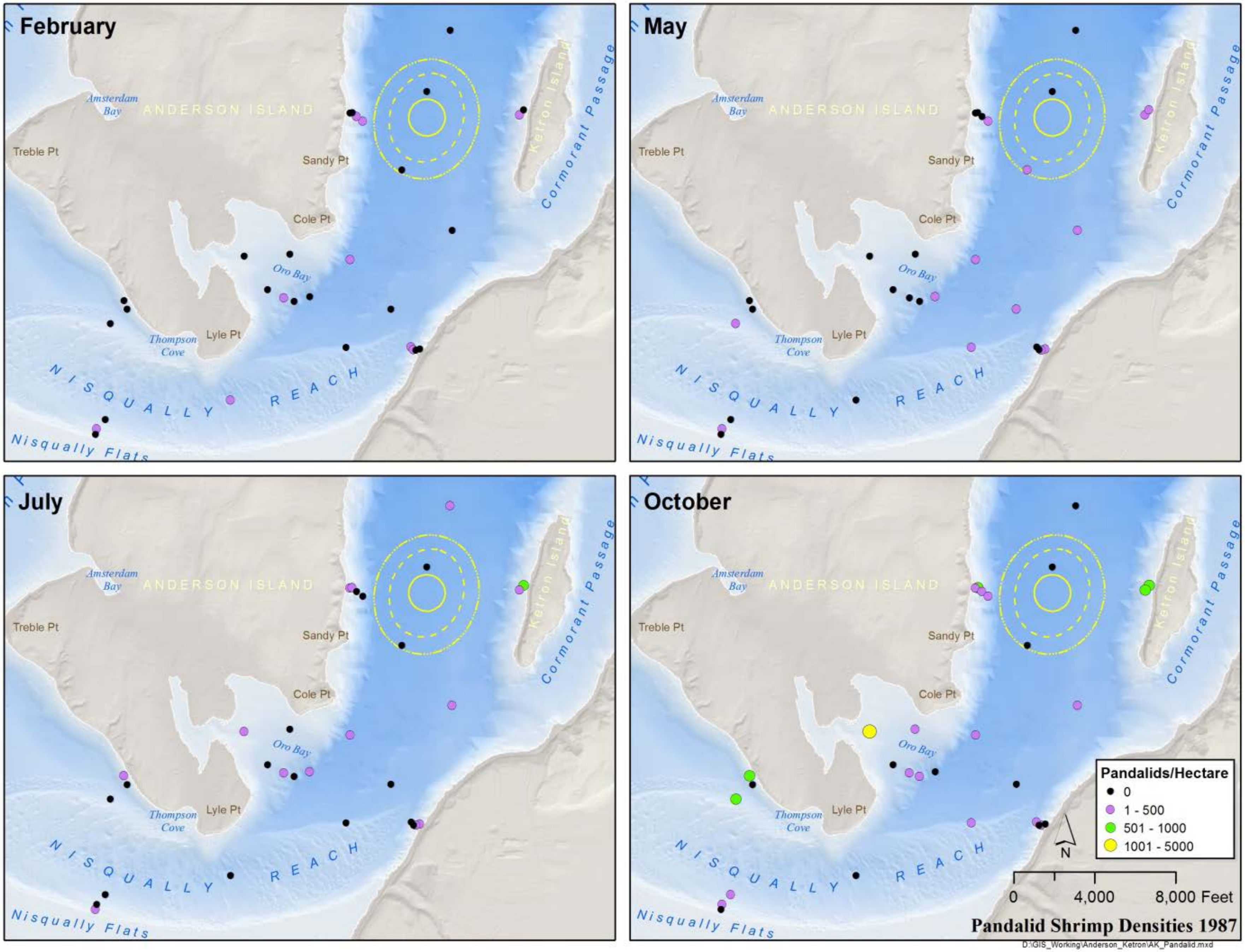


Figure 16. Pandalid Shrimp Density (all species combined) in the Vicinity of the Anderson/Ketron site in 1987.

Species-specific graphics for Pandalid shrimp are displayed in Figures 17-28. Following is a key for these figures, with both common and scientific names provided:

- Sidestripe Shrimp (*Pandalopsis dispar*)
- Dock Shrimp (*Pandalus danae*)
- Coonstripe Shrimp (*Pandalus hypsinotis*)
- Spot Prawns (*Pandalus platyceros*)
- Alaskan Pink Shrimp (*Pandalus eous*)
- Smooth Pink Shrimp (*Pandalus jordani*)
- Yellowleg Shrimp (*Pandalus tridens*)
- Unidentified Pandalid (*Pandalus sp.*)

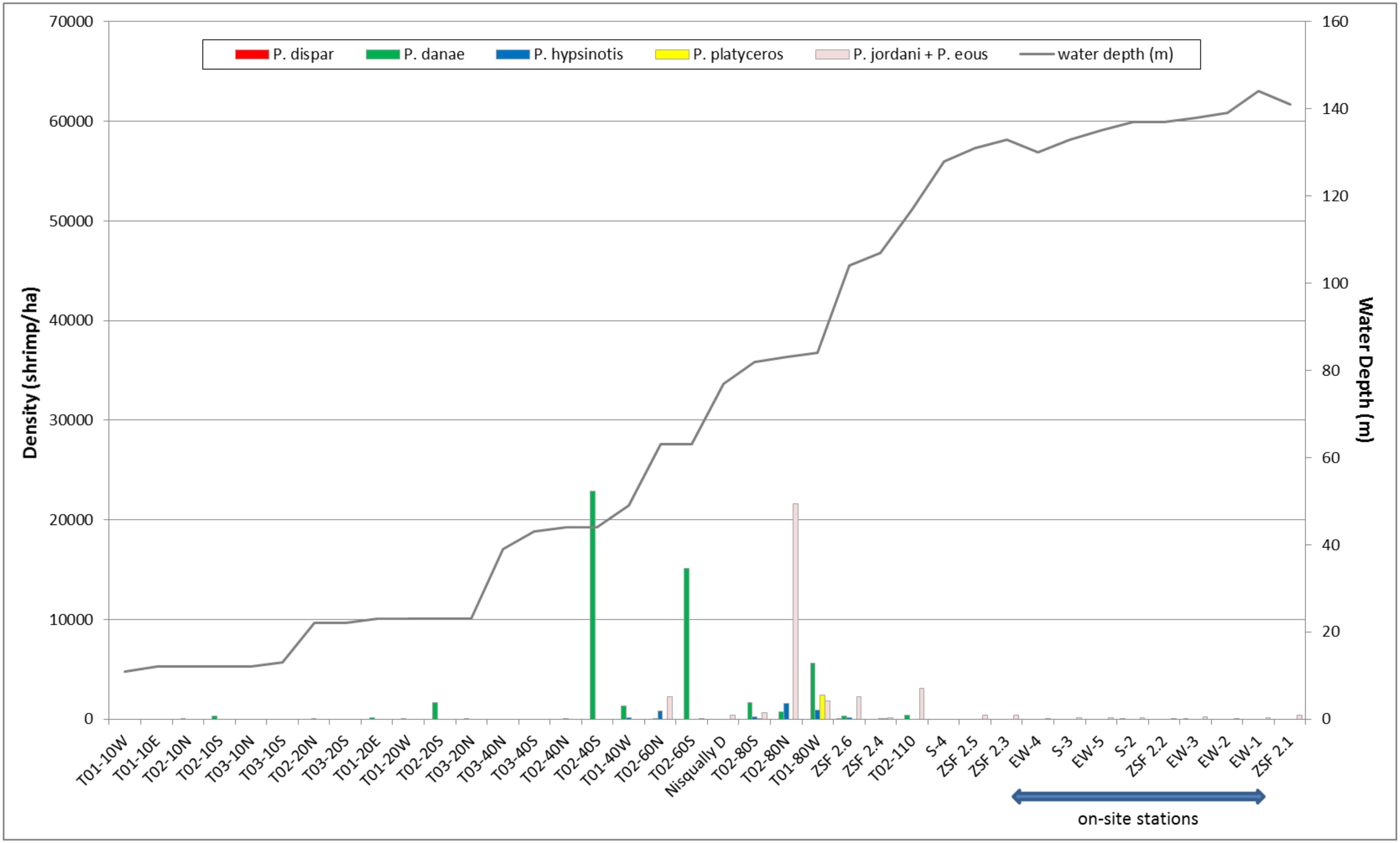


Figure 17. Pandalid Shrimp Density (linear scale) by Species and Depth – February, 2015

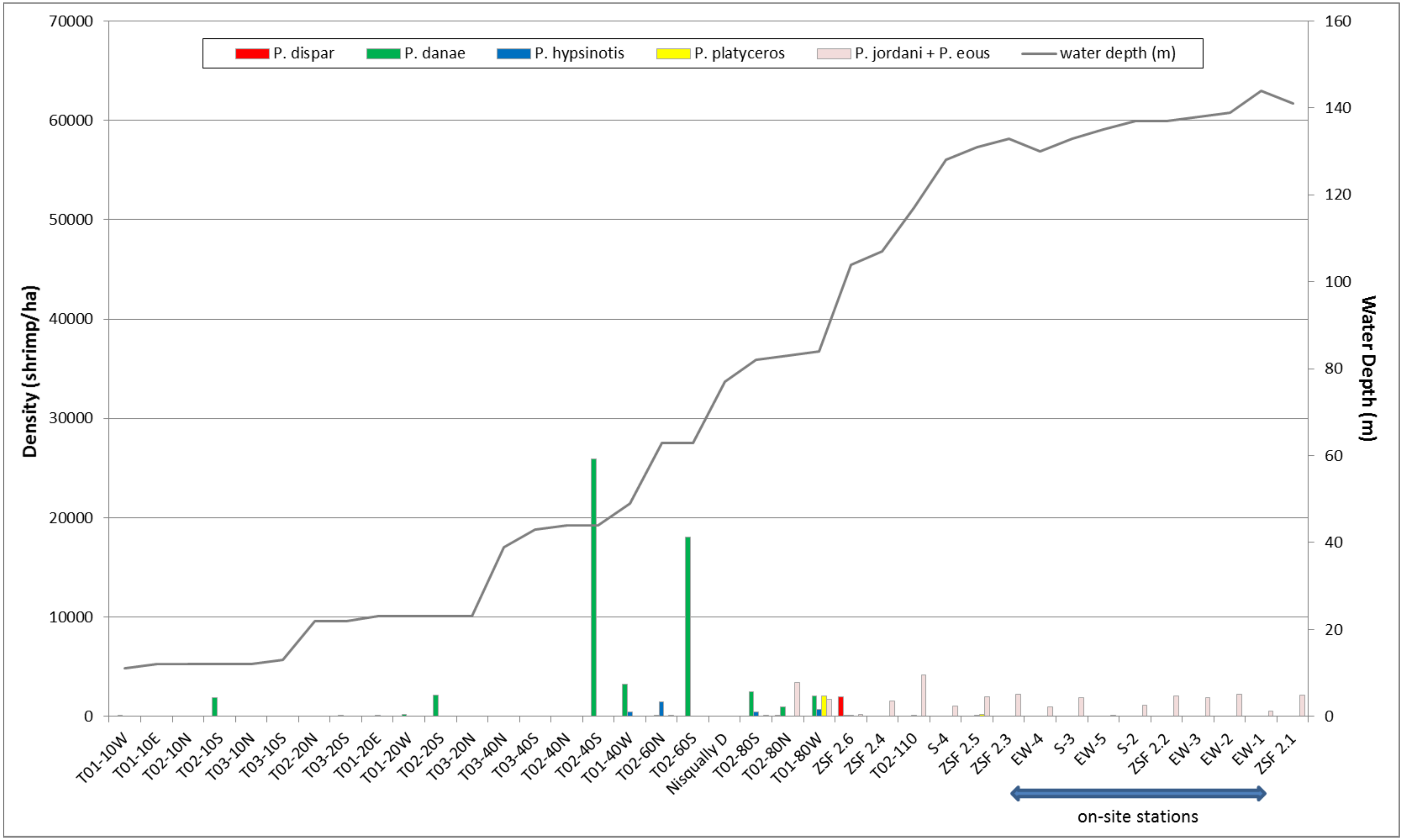


Figure 18. Pandalid Shrimp Density (linear scale) by Species and Depth – May, 2015

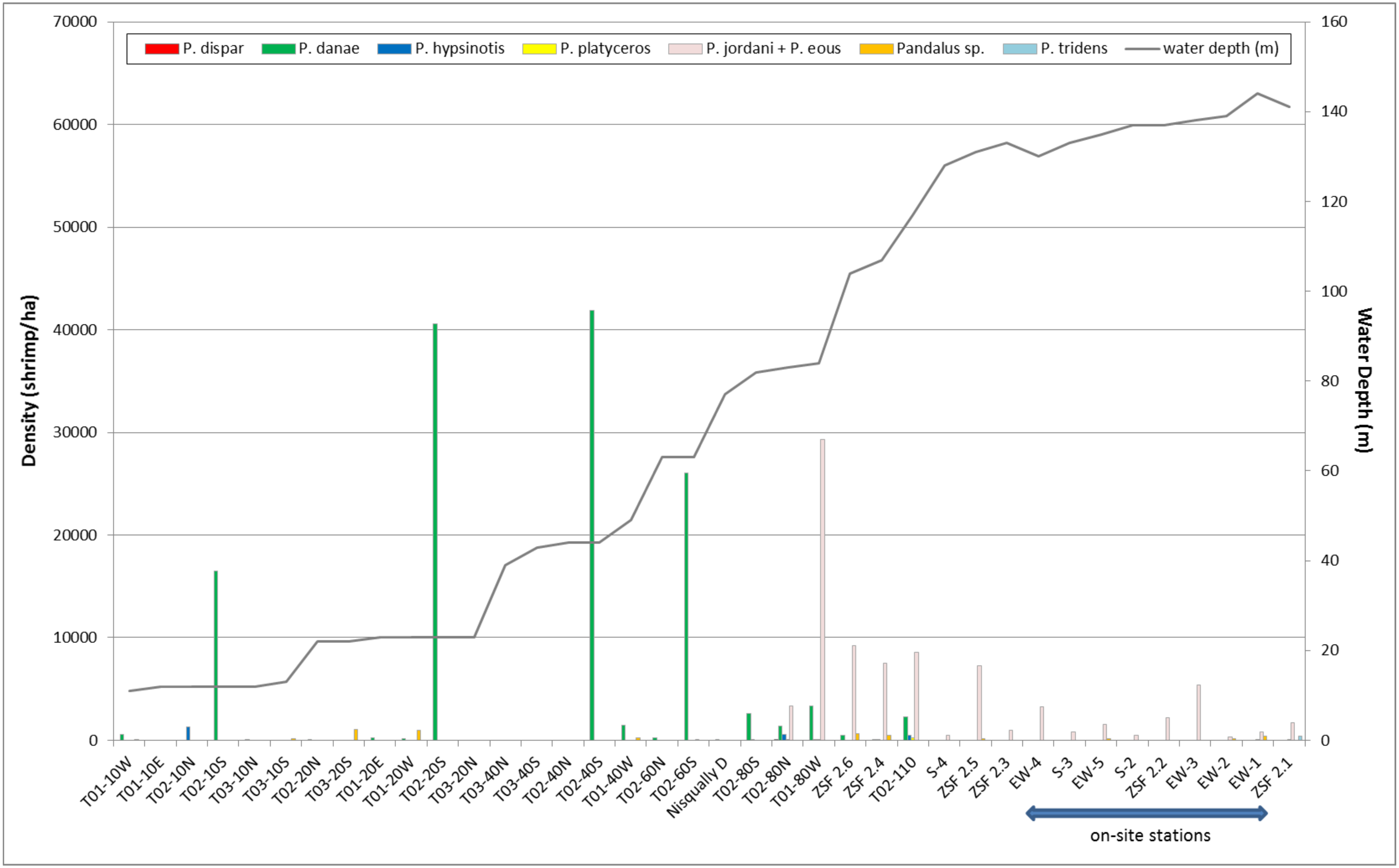


Figure 19. Pandalid Shrimp Density (linear scale) by Species and Depth – July, 2014

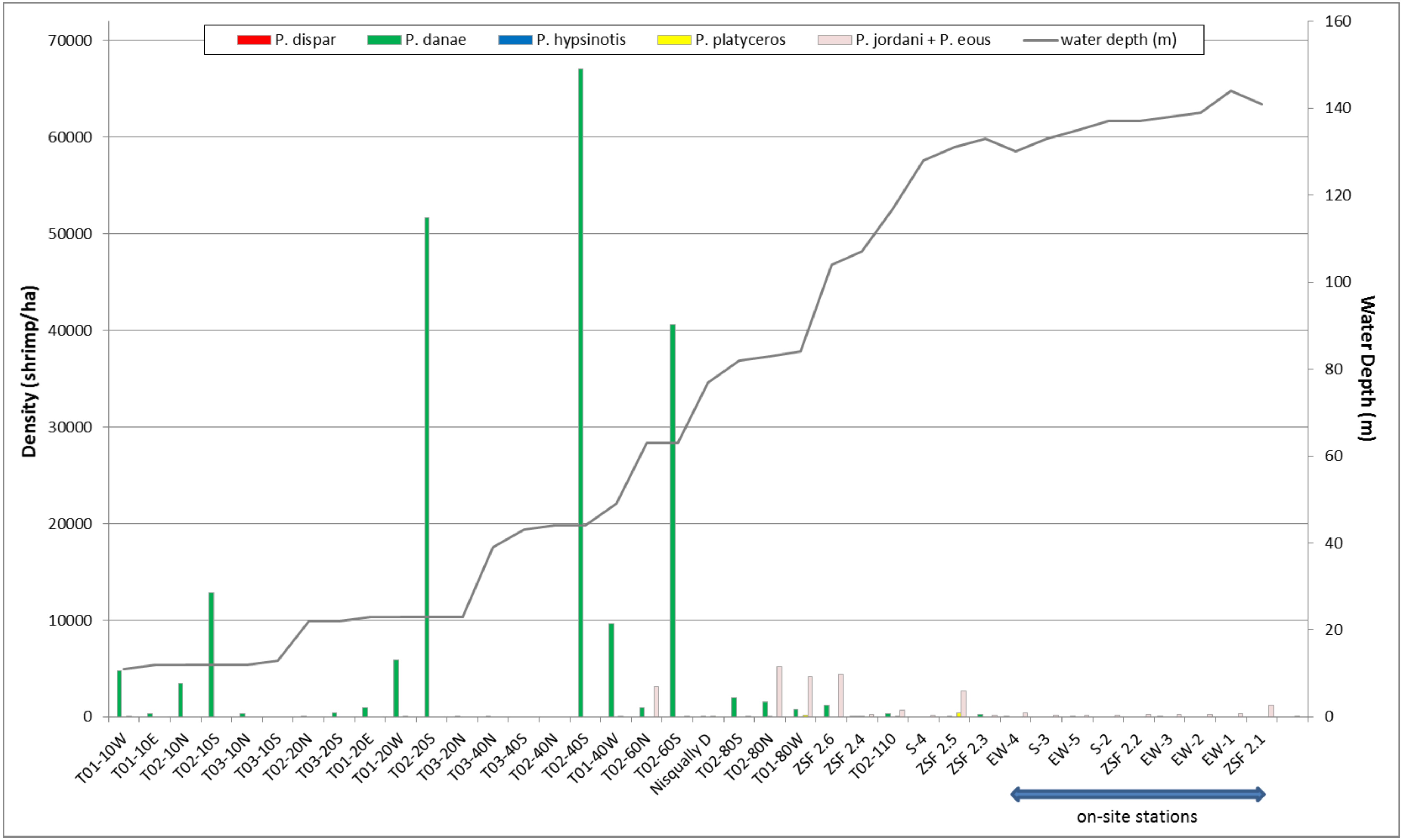


Figure 20. Pandalid Shrimp Density (linear scale) by Species and Depth– October, 2014

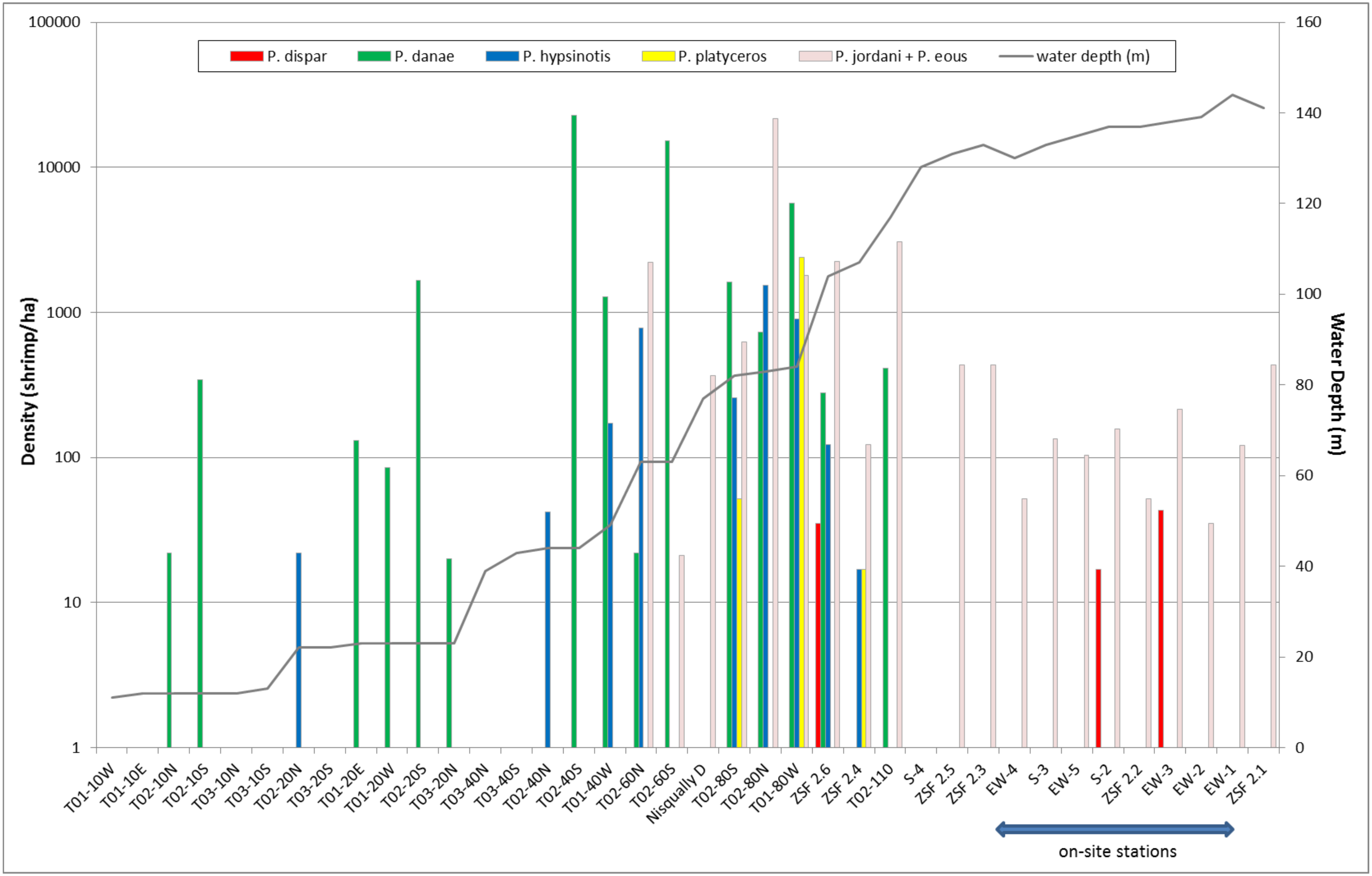


Figure 21. Pandalid Shrimp Density (log scale) by Species and Depth – February, 2015

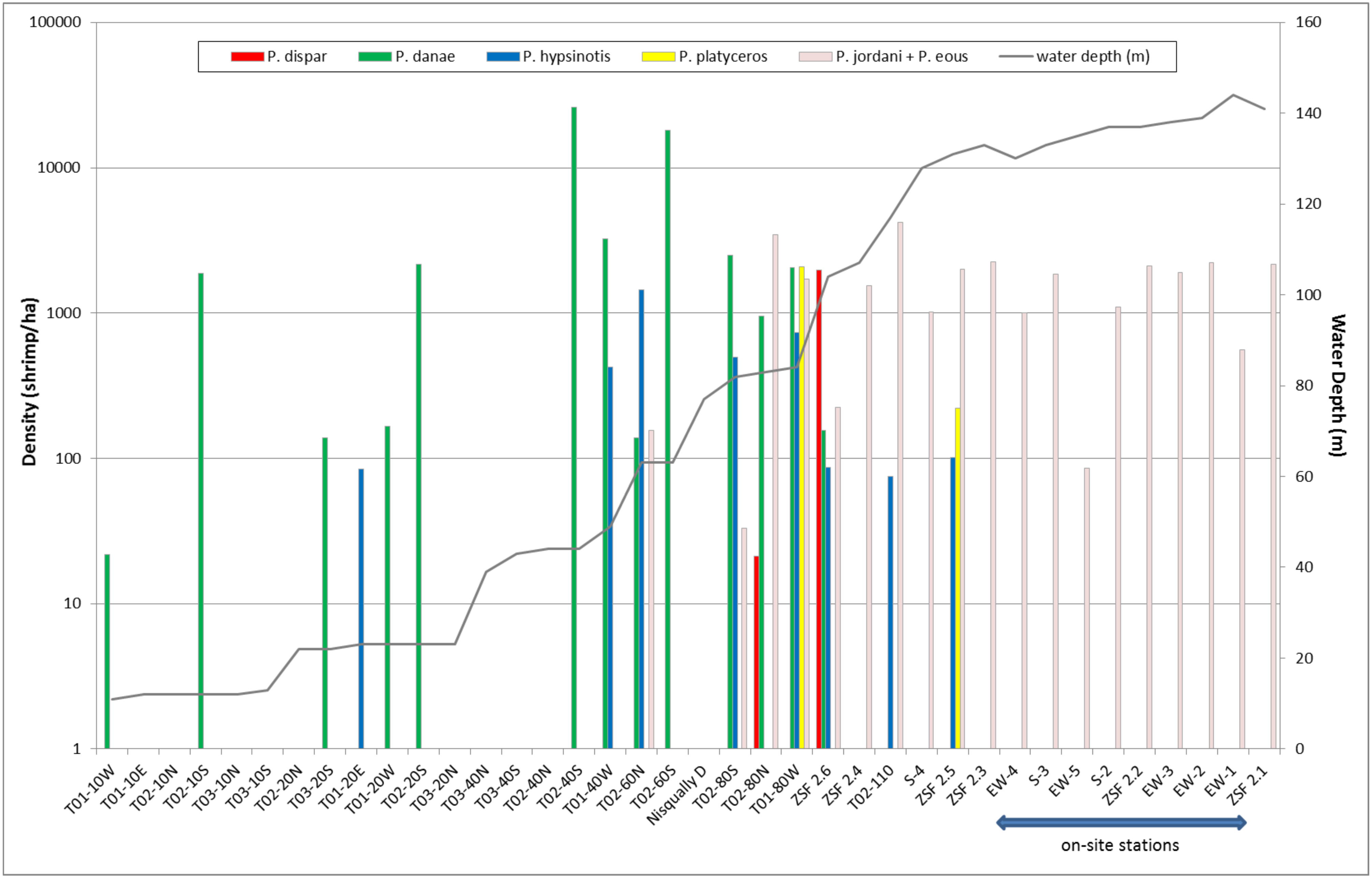


Figure 22. Pandalid Shrimp Density (log scale) by Species and Depth – May, 2015

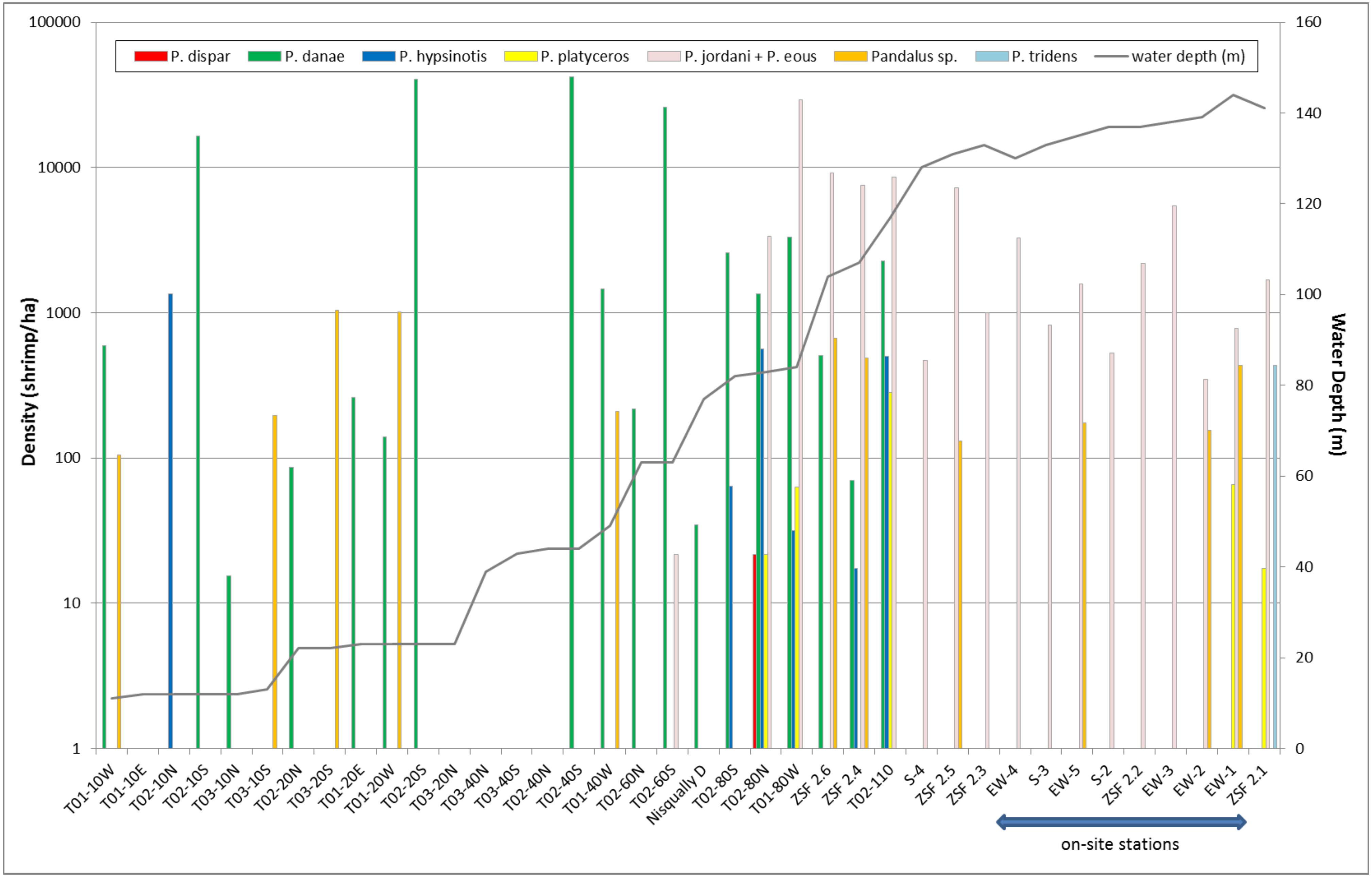


Figure 23. Pandalid Shrimp Density (log scale) by Species and Depth – July, 2014

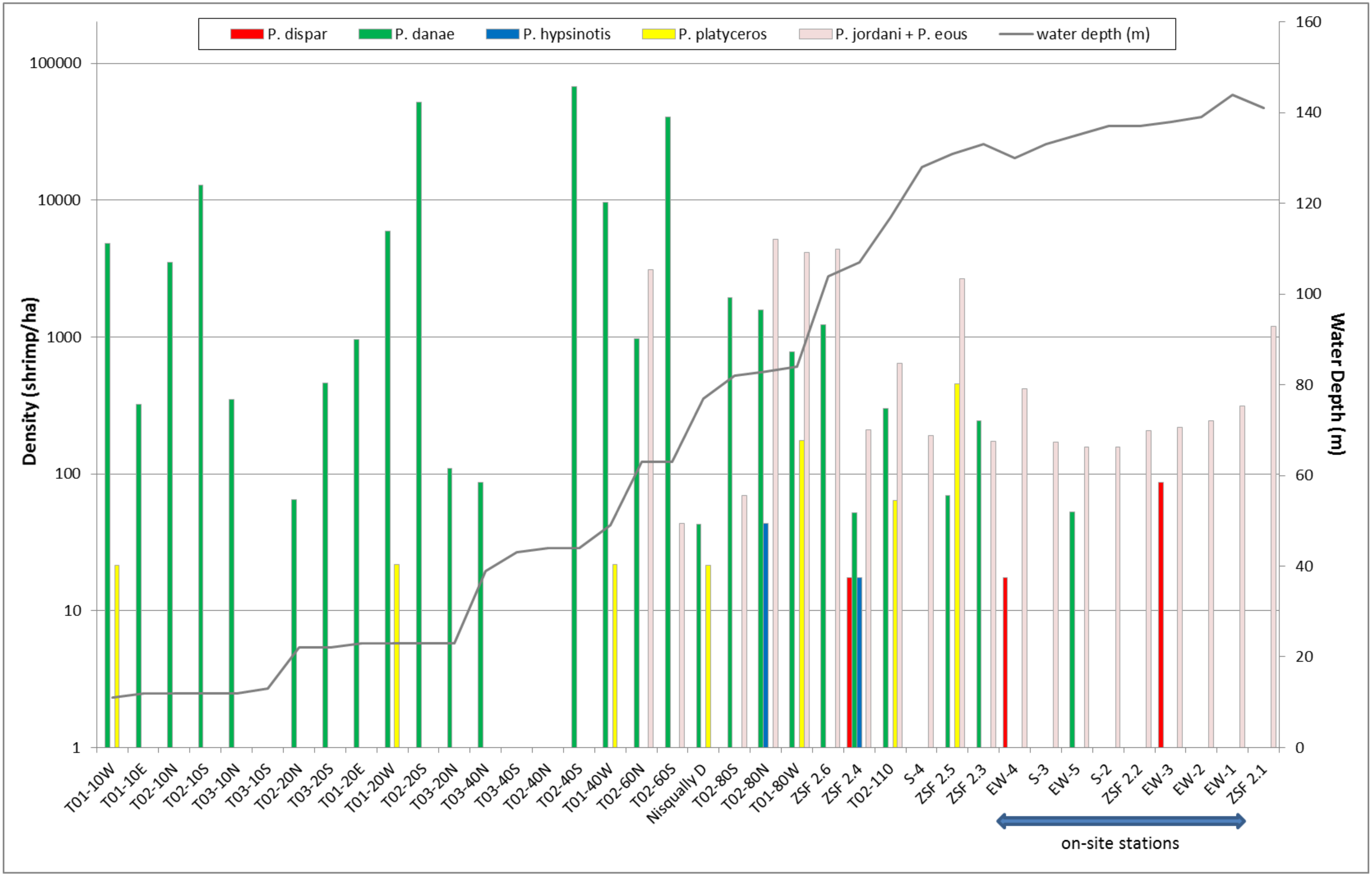


Figure 24. Pandalid Shrimp Density (log scale) by Species and Depth – October, 2014

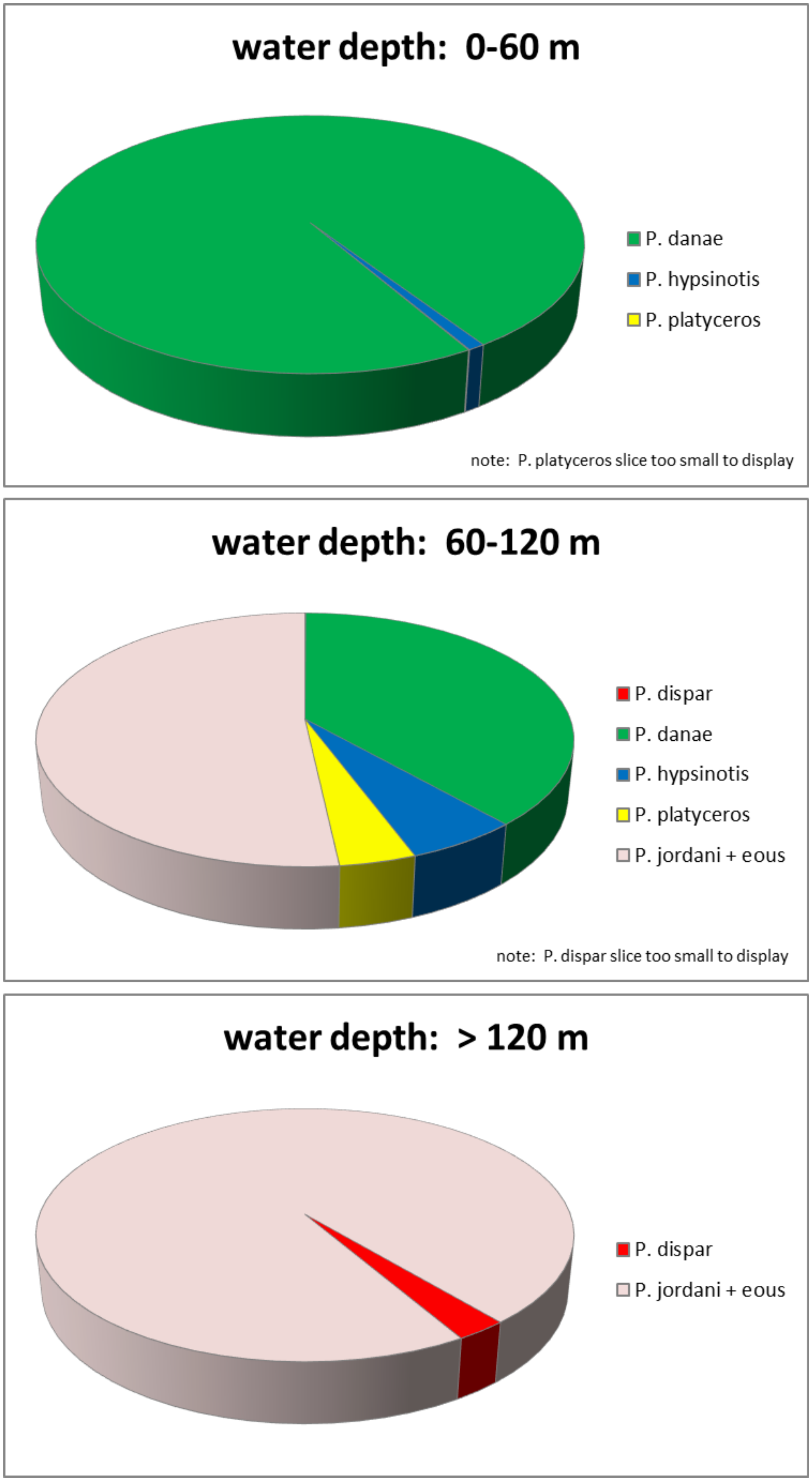


Figure 25. Relative Abundance of Pandalid Shrimp Species by Depth (m) – February, 2015

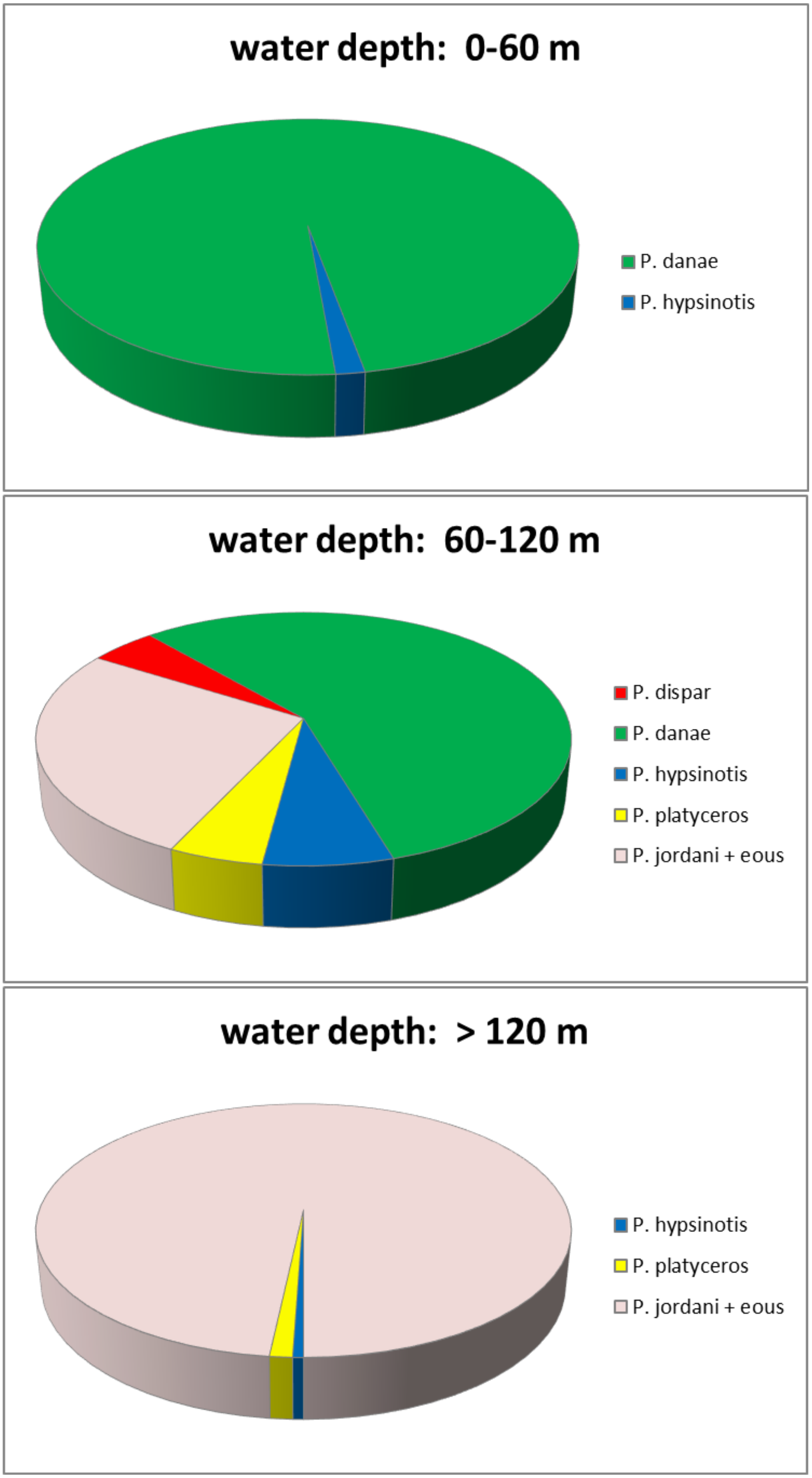
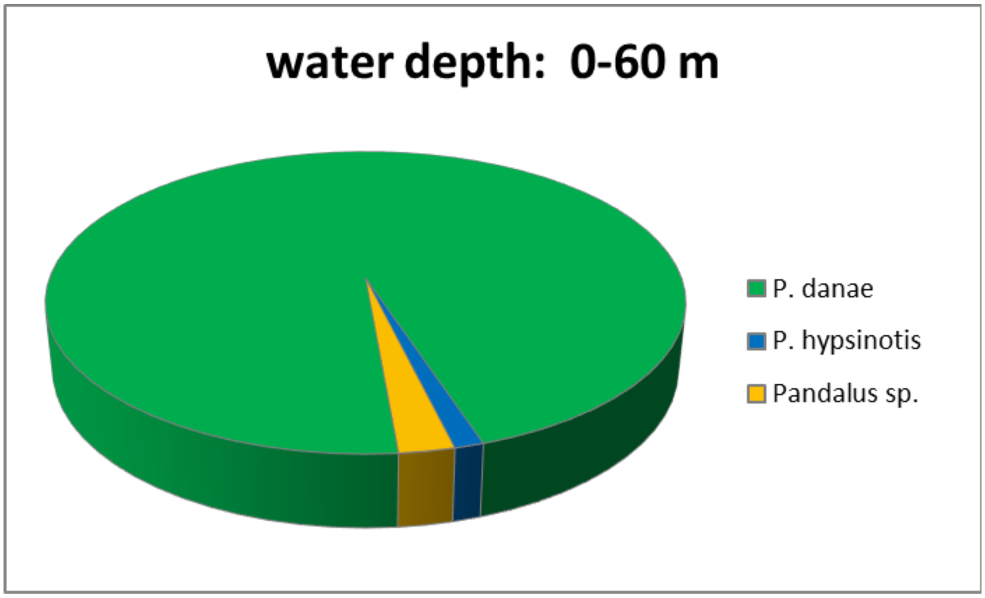
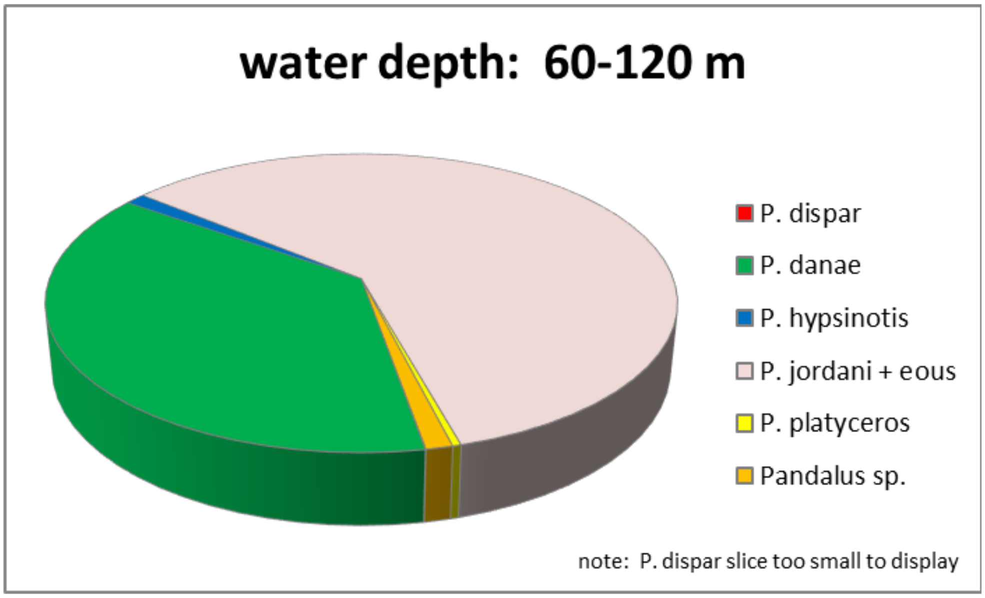


Figure 26. Relative Abundance of Pandalid Shrimp Species by Depth (m) – May, 2015





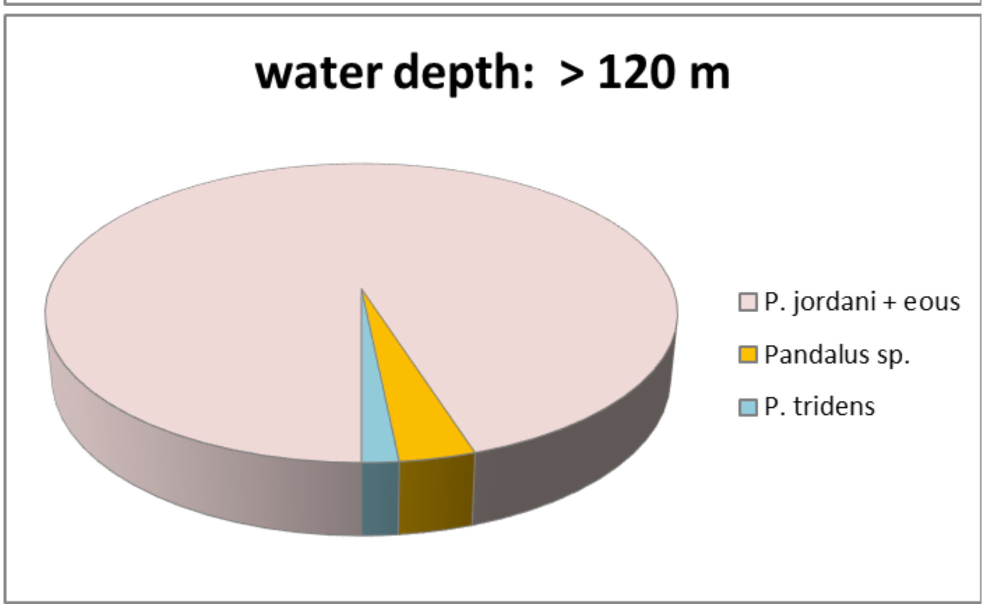


Figure 27. Relative Abundance of Pandalid Shrimp Species by Depth (m) – July, 2014

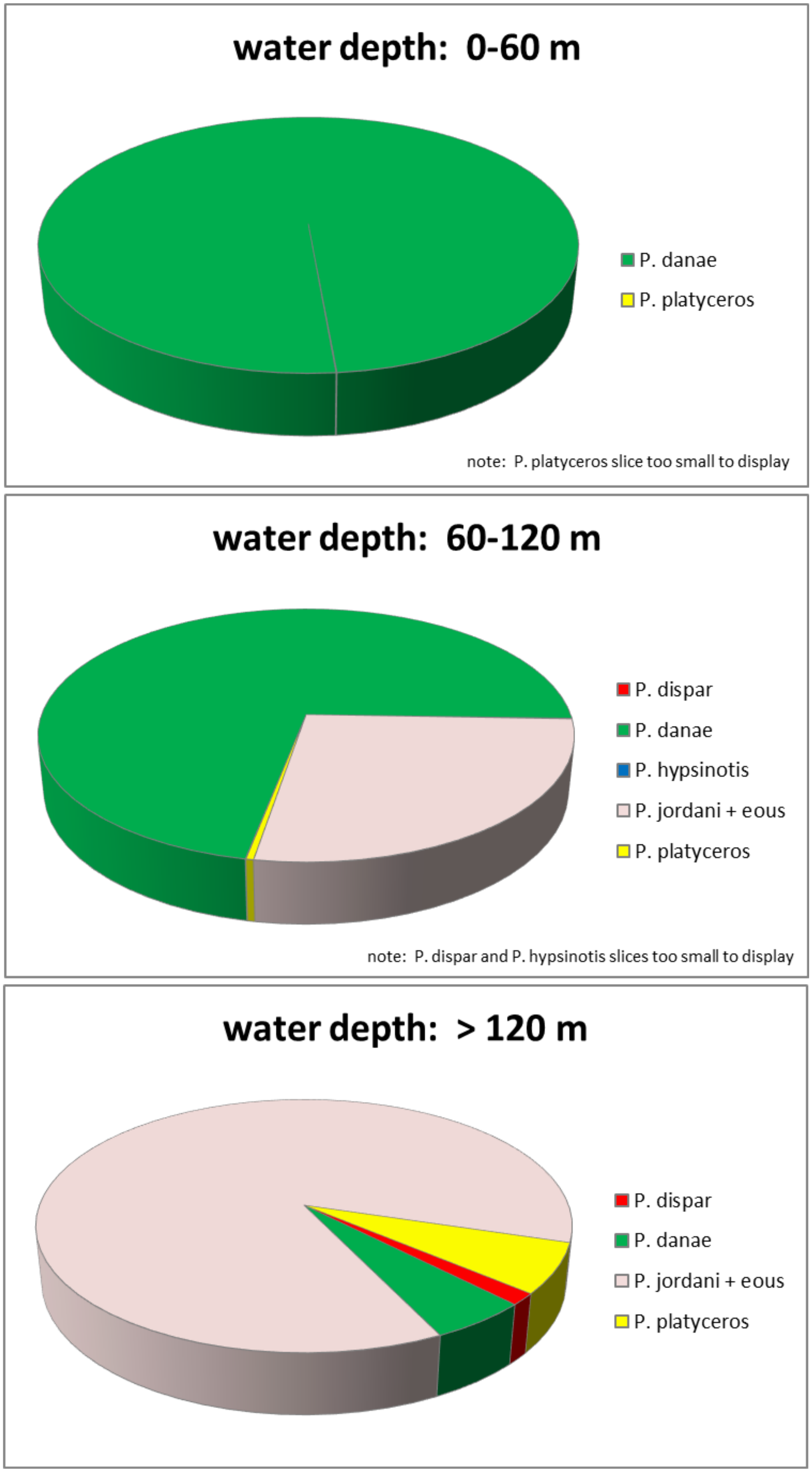


Figure 28. Relative Abundance of Pandalid Shrimp Species by Depth (m) – October, 2014

3.3 Sea Cucumbers

2014-2015 Summary

The commercially-harvested sea cucumber *Parastichopus californicus* was occasionally abundant over the course of the 2014-2015 investigation. For all 38 stations sampled in 2014-2015, the mean density of *P. californicus* for all four seasons was 70 individuals/ha, with the quarterly abundance ranging from 47 individuals/ha in July to 82 individuals/ha in May (Appendix B). In general *P. californicus* was most abundant in shallower water depths (10-40 m) at nearshore stations, particularly off the west coast of Ketron Island; the east and southwest coasts of Anderson Island; and the south stations of Transect 2 (Figure 29 and Appendix B). A single sea cucumber was captured within the Anderson/Ketron disposal site boundary during the study, occurring in July at station ZSF 2.2.

Comparison to 1987 Siting Study

To allow for an unbiased comparison of the 2014-2015 study to the 1987 siting study, a summary comparison of the same 30 stations sampled in 1987 was conducted. In 2014-2015, the mean density of *P. californicus* for all four seasons at these 30 stations was 89 individuals/ha, ranging from 60 individuals/ha in July to 104 individuals/ha in May (Appendix B). During the 1987 siting study, *P. californicus* were approximately twice as abundant as in 2014-2015 (Figure 30 and Appendix B). For the 30 stations sampled in 1987, the mean density for all four seasons for *P. californicus* was 167 individuals/ha, with the quarterly abundance ranging from 124 individuals/ha in July to 197 individuals/ha in October (Appendix B). On-site abundance was comparable in the studies, with no *P. californicus* found at the one on-site station in 1987 during any of the quarterly trawls, and only one individual found within the disposal site boundary in 2014-2015.

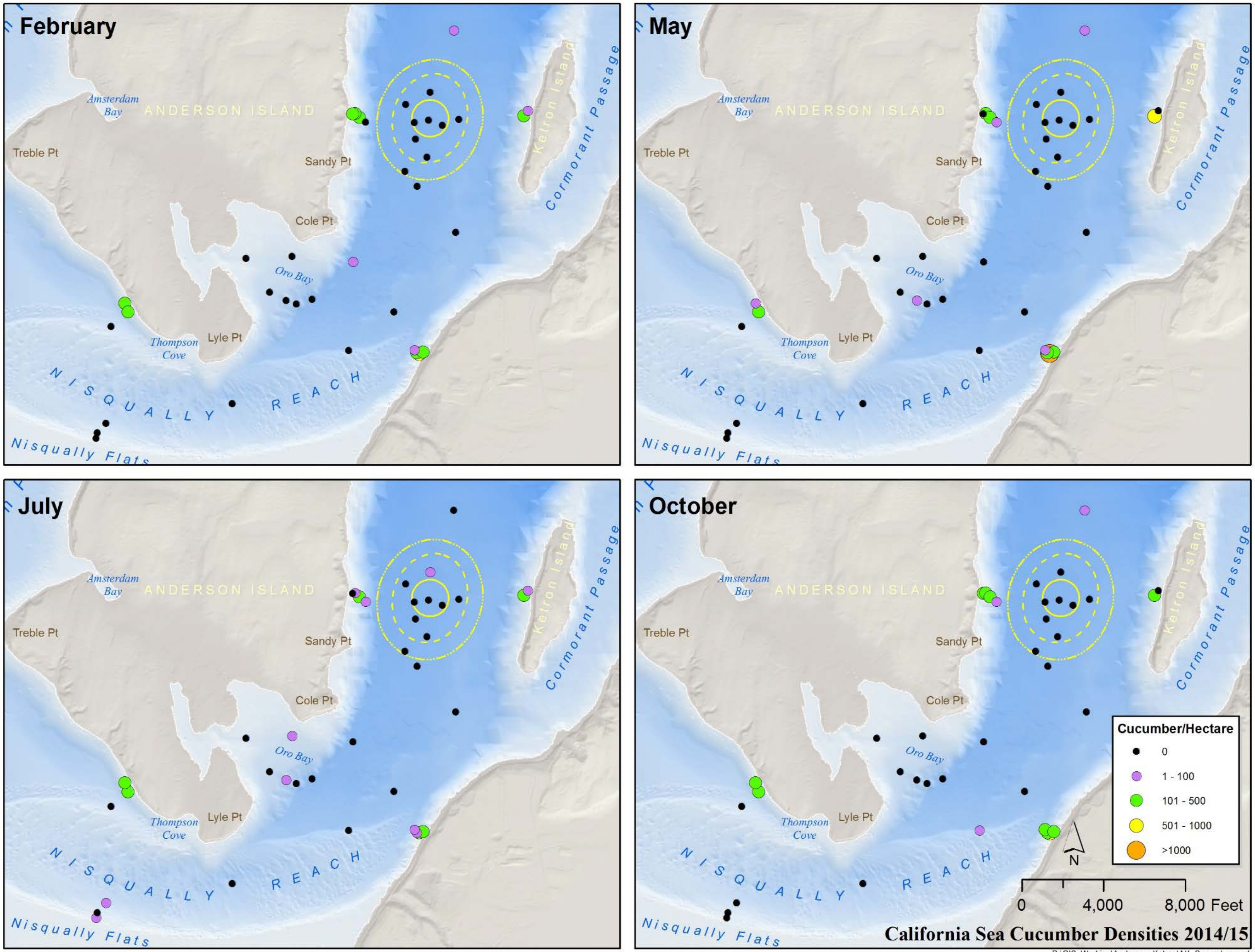


Figure 29. Density of the California sea cucumber (*Parastichopus californicus*) in the Vicinity of the Anderson/Ketron site in 2014-2015.

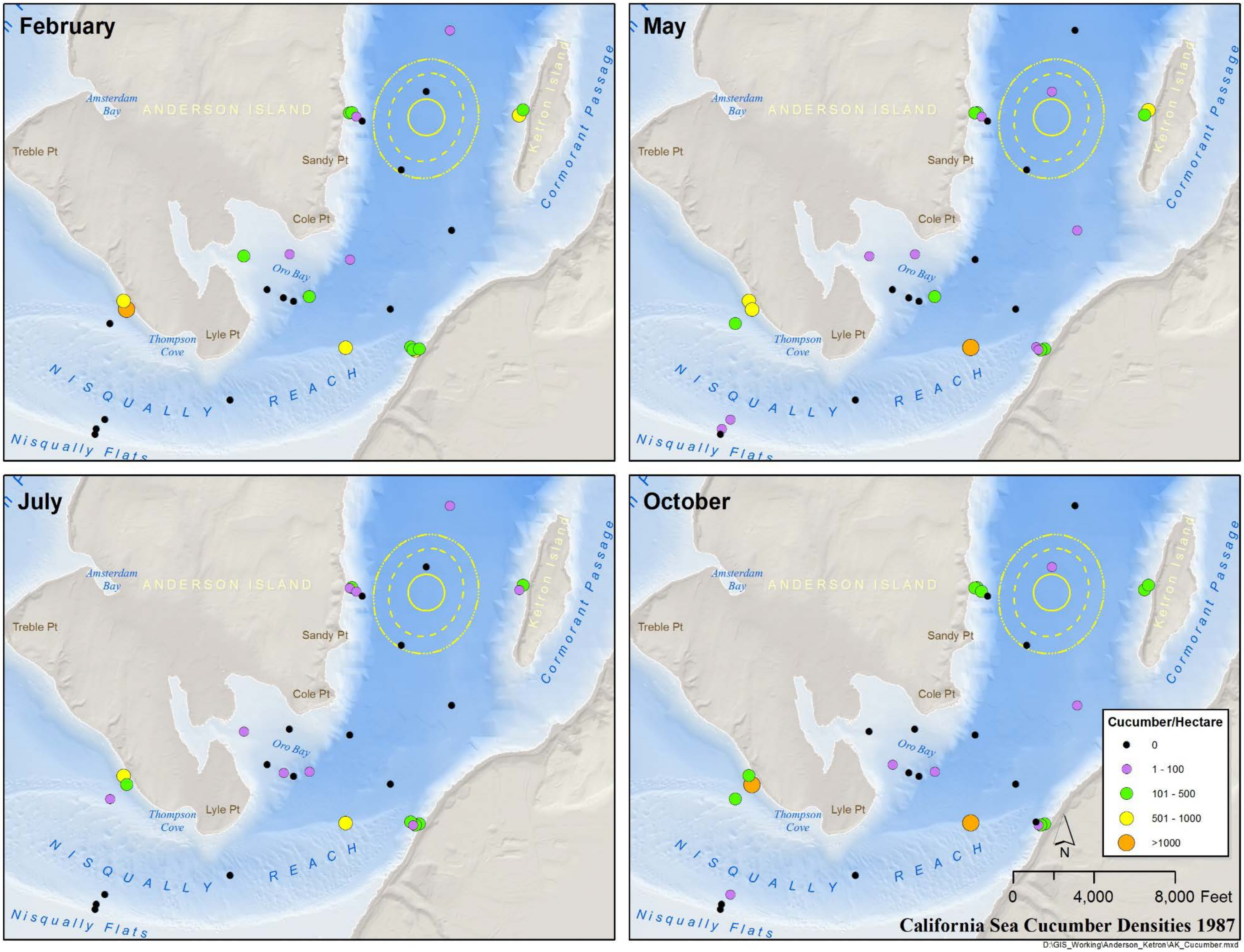


Figure 30. Density of the California sea cucumber (*Parastichopus californicus*) in the Vicinity of the Anderson/Ketron site in 1987.

3.4 Sea Stars

2014-2015 Summary

The classification "sea stars" from the 1987 siting study combined all species of sea stars. To allow for between-study comparisons, this group classification was retained for the current study. For all 38 stations sampled in 2014-2015, the mean density for all four seasons for sea stars was 210 individuals/ha, with the quarterly abundance ranging from 117 individuals/ha in October to 427 individuals/ha in July (Appendix B). Sea stars were well distributed spatially over the course of the 2014-2015 investigation, but occurred in greater numbers at the shallower stations (Figure 31 and Appendix B). The highest densities were found at the south stations of Transect 2 (May and July); near the southwest coast of Anderson Island (year-round); and at the outer limits of Oro Bay (October).

Comparison to 1987 Siting Study

To allow for an unbiased comparison of the 2014-2015 study to the 1987 siting study, a summary comparison of the same 30 stations sampled in 1987 was conducted. In 2014-2015, the mean density of sea stars over all four seasons at these 30 stations was 263 individuals/ha, ranging from 146 individuals/ha in February to 539 individuals/ha in July (Figure 31 and Appendix B). During the 1987 siting study, sea stars were of approximately the same abundance in three of the four seasons, with July being the outlier. In July, the mean density was only 169 individuals/ha in 1987, compared to the mean density of 539 individuals/ha that month in 2014-2015. The lower density of sea stars in July of 1987 resulted in a mean density that year over all four seasons of only 178 individuals/ha, which was approximately 30% less than the yearly mean for 2014-2015. The quarterly densities in 1987 ranged from 139 individuals/ha in February to 218 individuals/ha in May (Figure 32 and Appendix B).

On-site abundance was relatively low in both studies, with no sea stars found at the one on-site station in February and July of 1987 and fewer than 20 sea stars/ha in May and October. Sea stars were collected at four of the eight on-site stations during at least one month in the 2014-2015 study, with a mean density over all four seasons at all on-site stations of 13 individuals/ha and a maximum density of 173 sea stars/ha in May at station EW-3.

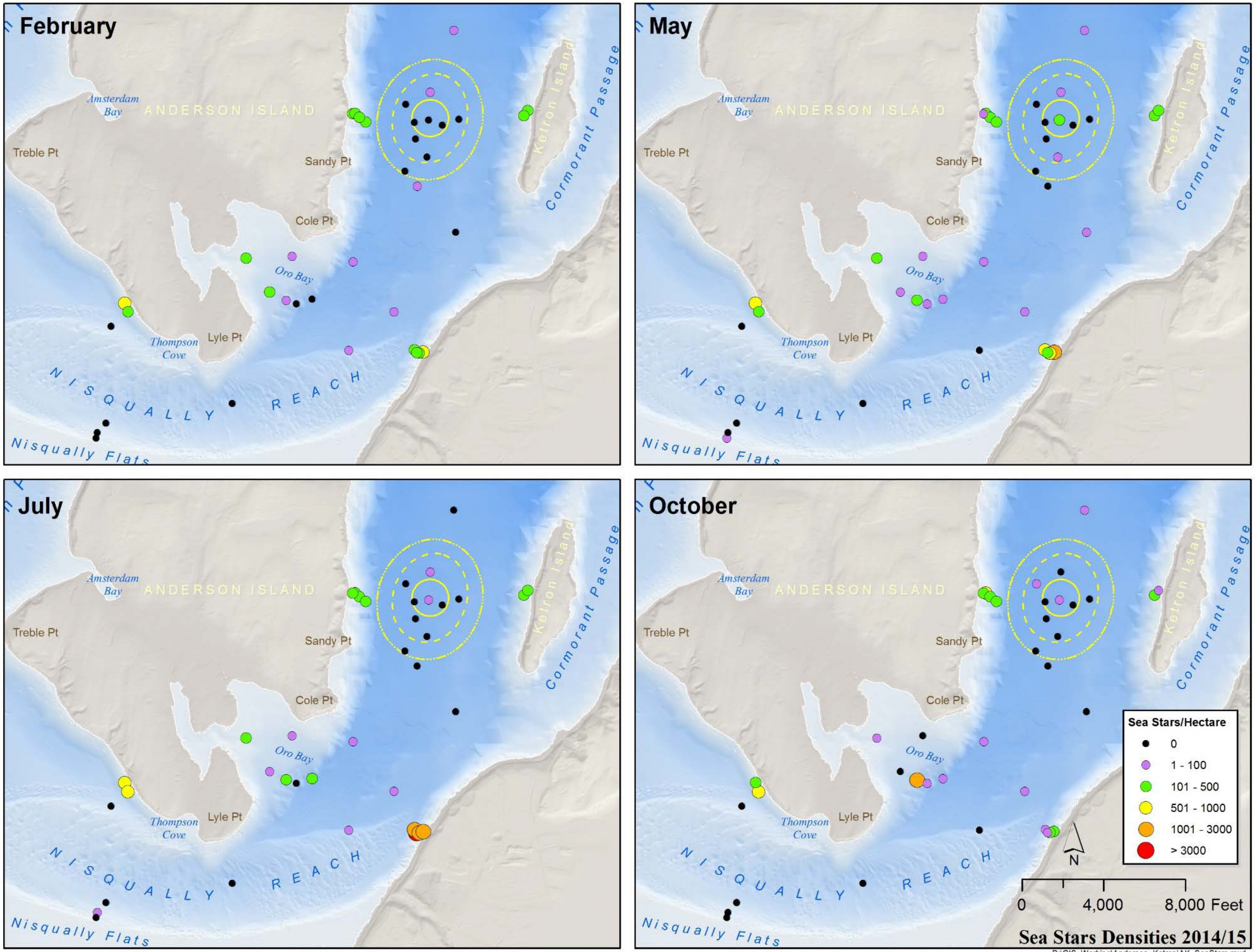


Figure 31. Sea Star Density (all species combined) in the Vicinity of the Anderson/Ketron site in 2014-2015.

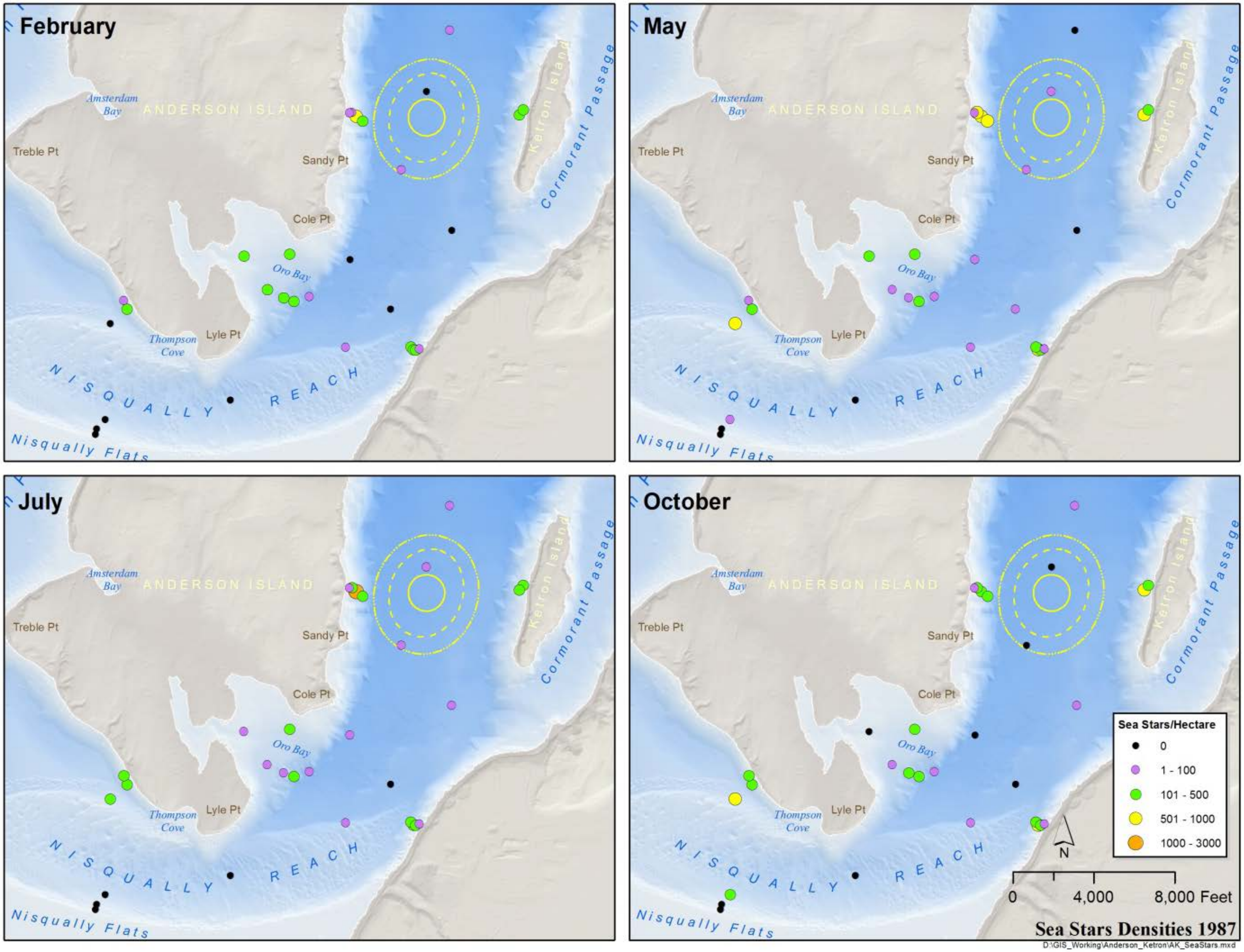


Figure 32. Sea Star Density (all species combined) in the Vicinity of the Anderson/Ketron site in 1987.

3.5 Other Invertebrates

A variety of other invertebrates were captured during the 2014-2015 beam trawl study. General groupings included anemones, nudibranchs, decorator crabs, kelp crabs, hermit crabs, shore crabs, small Heptacarpid shrimp, Spirontocarid shrimp, Crangon shrimp, and the occasional octopus or sea urchin (Herrera and NewFields 2015a, b, c, d). The original 1987 siting study focused on commercial species, with very little information provided on non-commercial species. Within the category of "other invertebrates," the 1987 trawls only included summaries for sea cucumbers and sea stars (Dinnel et al. 1988), provided above. Therefore, for the category of "other invertebrates," it is not possible to compare the 2014-2015 study to the 1987 siting study.

The 2014-2015 data associated with the "other invertebrate" category can be found in Appendix E and the four seasonal cruise reports (Herrera and NewFields 2015a, b, c, d).

3.6 Fish

During the 1987 PSDDA siting study, fish were surveyed using an otter trawl (Dinnel et al. 1987a,b,c,d,e, 1988, Donnelly et al. 1988). An otter trawl is an effective research tool designed to capture fish, with the ability to capture larger and faster fish as it is towed at a slightly faster speed than a beam trawl and has a larger opening at the mouth of the net. A beam trawl was selected for the 2014-2015 study because the goal of this study was to assess the current distribution and abundance of sport and commercially harvested invertebrate resources (e.g. crab and shrimp). The slower moving beam trawl is a much more effective tool at capturing smaller and slower epibenthic invertebrates than at capturing fish. Because of the difference in trawling methods, the fish capture data from the 2014-2015 beam trawl are not comparable to the trawl data from the 1987 investigations.

Nearly 50 species of mostly demersal fish species were captured during the 2014-2015 beam trawl study (Herrera and NewFields 2015a, b, c, d; Appendix F). The three most prevalent fish captured in the beam trawl tows included blackbelly eelpouts, roughback sculpin and plainfin midshipman. Other fish captured included a variety of sculpins, soles, poachers, sanddabs, snailfish, and gunnels, among others (Herrera and NewFields 2015a, b, c, d). Density estimates provided in Appendix F should be considered with caution due to the sampling method used. Smaller species such as gunnels, pipefish, and juvenile eelpouts consistently squeezed through the holes in the mesh of the beam trawl before it could be hauled on the deck of the vessel. For other species such as skates, only smaller juveniles were captured, as adults would be expected to easily avoid the slow-moving beam trawl. Therefore, Appendix F should not be broadly applied to all fish species as a tool for estimating density in the study area.

4.0 Discussion and Conclusions

4.1 2014-2015 vs. 1987

A principal goal of the 2014-2015 study was to compare the current demersal resources in the vicinity of the Anderson/Ketron Island disposal site to the original 1987 siting study to detect changes that may have occurred in the past 28 years. To maximize consistency between the two studies, the 2014-2015 study was conducted at the same 30 stations investigated during the 1987 siting study (with eight additional stations near or within the disposal site), and utilized the same captain, research vessel, and beam trawl. Both studies focused on "invertebrate species of actual or potential commercial and sport concern." These included: Dungeness crab, "rock crab" (red rock crab and graceful rock crab combined), Pandalid shrimp, and sea cucumbers. The siting study also provided information on sea star density, as did the present study. One difficulty in comparing the 2014-2015 and 1987 studies stems from the fact that the 1987 study included only one on-site station. This small sample size must be kept in mind when assessing the comparisons made in the following sections.

4.1.1 Crab

Dungeness crabs (*Cancer magister*) were found to be relatively sparse in the study area in 1987. Although they were approximately two and a half times more abundant in 2014-2015 at the same 30 stations surveyed in 1987, abundance of Dungeness crabs was still low. Size frequency distributions for both studies were indicative of 3-5 year old adult crabs, suggesting that successful recruitment in the Nisqually Reach is sporadic. The absence of smaller Dungeness crabs was also noted in WDFW crab test fishing data collected throughout Marine Area 13 (MA13) in May 2015 (Don Velasquez, pers. comm. 2016). Whether local recruitment is dependent on resident female crabs or crabs north of Tacoma Narrows remains unknown. Additionally, it is unknown whether sufficient recruitment habitat is present within this area. The small number of large male Dungeness crab was assumed to be predominantly a function of their removal by sport and Treaty crabbers. WDFW does not allow State commercial fisheries in MA13, but a Treaty commercial crab fishery does exist along with a limited Treaty subsistence and ceremonial fishery (Don Rothaus, pers. comm. 2016). While the overall abundance of Dungeness crabs in 2014-2015 was approximately two and a half times what it was in 1987, the density of adult males of legal size (> 159 mm) was about the same in both studies (0.85 legal crabs/ha in 2014-2015 compared to 0.78 legal crabs/ha in 1987). Females and juveniles accounted for the majority of the overall density increase.

Another factor potentially contributing to relatively low numbers of larger male and female Dungeness crabs in this region is the continued presence of derelict pots. A number of derelict shrimp and crab pots were detected and removed during the course of this study, with a few of these including large crabs or molts of large crabs no longer in the pot. Derelict crab pots, some with crabs inside, were caught on the beam trawl in each quarter of the 2014-2015 study (Herrera and NewFields 2015a, b, c, d). Nearly all of these pots appeared to have been under water for an extended period of time, based on the biofouling of the crab pot itself or on the rope attached to the pot. A number of the derelict pots were not outfitted with an escape cord, and were still actively fishing as "ghost pots." Within Washington State waters, each crab, shrimp, or crawfish pot must be equipped with a biodegradable device (rot/escape cord). The Northwest Straits Initiative estimates that there are approximately 12,193 crab pots lost in Puget Sound each year (Antonelis et al. 2010). A single lost crab pot without escape cord can kill up to 30 crabs until deterioration (Antonelis et al. 2010). Whether the prevalence of derelict pots in the study area has substantially reduced Dungeness crab density in the study area is unknown. However, WDFW suggested that derelict pots are not likely the primary reason for the low numbers of larger Dungeness crabs, since many other areas of Puget Sound have significant problems with derelict traps and yet have consistently high densities of large Dungeness crabs (Don Velasquez, pers. comm. 2016). This opinion is supported by data from the study, which showed that large female crabs (> 159 mm) outnumbered large males by more than two to one in 2014-2015. While large females accounted for only 6% of the total catch in 1987, they made up 20% of the total catch in 2014-2015. The higher abundance of large adult females compared to large adult males, and the higher fraction of large adult females in 2014-2015 compared to 1987 is evidence that the impact of derelict pots has not worsened in the intervening years and that recreational and Treaty crabbing are likely the primary reason for the low numbers of large adult males.

"Rock crabs" (*Cancer productus* and *C. gracilis*) were more prolific and more broadly distributed than Dungeness crabs for both studies. For the same 30 stations sampled, "rock crabs" were much more abundant in 2014-2015 (more than 8 times) than in 1987. *Cancer productus*, utilized by some sport and Treaty crabbers, was much less abundant than the smaller, more prolific, *C. gracilis*, accounting for only 15% of the total number of "rock crabs" collected. This was similar to the 10% reported for the 1987 study (Dinnel et al. 1988). Using these percentages, the average density of *C. productus* over all 30 stations and seasons was approximately 5 crabs/ha in 1987 and 56 crabs/ha in 2014-2015, a ten-fold increase. In contrast to *C. magister*, size distributions for *C. productus* and *C. gracilis* had a better representation of smaller individuals within the limits of what was retained by the mesh size of the net.

Tanner crabs (*Chionoecetes bairdi*) were not captured anywhere during the 1987 siting study, while four adults were captured in October 2014. *Chionoecetes bairdi* occurrence may be increasing in portions of Puget Sound, with at least one region supporting small fisheries (D. Velasquez, pers. comm. 2014). However, the presence of four individuals is not sufficient to determine any trends.

4.1.2 Pandalid shrimp

Pandalid shrimp, as a collective, were found to be relatively sparse in the study area in 1987, with no apparent patterns in their distribution. However, in the 2014-2015 study, Pandalid shrimp were extremely abundant, most notably at the T02 stations east of Oro Bay, and at the T01 stations just off the eastern shore of Anderson Island. This was due, in large part, to the abundance of both juvenile and adult dock shrimp (*Pandalus danae*) at some of these shallower stations. The yearly mean density for Pandalid shrimp in 1987 was 86 shrimp/ha, whereas the yearly mean density for Pandalid shrimp in 2014-2015 at the same 30 stations utilized in 1987 was nearly 60 times higher at 5,142 shrimp/ha. The most abundant species of Pandalid shrimp was *P. danae*, followed by the smooth pink shrimp (*P. jordani*) and Alaskan pink shrimp (*P. eous*). These same three species were also the most abundant of the Pandalids in 1987, albeit at lower densities. The recreationally sought-after spot prawn (*P. platyceros*) was one of the less common Pandalid shrimp in 2014-2015, similar to the 1987 siting study. This could be due, in part, to sport/Treaty fisheries in the area or, to a lesser extent, to the size-selective derelict shrimp pots that were discovered during the 2014-2015 study. It should be noted that there are currently no State-sanctioned or Treaty commercial fisheries in South Sound (Management Area 13). Therefore, Treaty harvest is confined to subsistence and ceremonial fisheries (Don Rothaus, pers. comm. 2016).

4.1.3 Sea Cucumbers

The commercially harvestable California sea cucumber (*Parastichopus californicus*) was considered plentiful during the 1987 siting study, although it was not well distributed throughout the study area. *Parastichopus californicus* was unevenly distributed again in 2014-2015, and occurred at lower abundance than in 1987. For all 30 stations sampled in 1987, the mean density for *P. californicus* was 167 individuals/ha, whereas in 2014-2015 for the same stations, the yearly mean density for *P. californicus* was 89 individuals/ha, roughly half that of the initial study. *Parastichopus californicus* was generally more abundant at the same shallow stations in 1987 and 2014-2015, including both the east and west stations of Transect 1; the south stations of Transect 2; and off the southwest shore of Anderson Island. The abundance of California sea cucumbers was lower in 2014-1015 at stations in and east of Oro Bay, particularly at station T02-80S, which had abundant *Parastichopus californicus* in 1987 but which had little presence of this species in 2014-2015.

The overall lower abundance of sea cucumbers in 2014-2015 compared to 1987 is possibly the result of intensive harvesting in years past, as has been demonstrated for the San Juan Islands (Carson et al., 2016). Harvest records from the period during which the Anderson-Ketron Island disposal site has been open (1989-present) appear to support this hypothesis, with the largest harvests reported early in this period and smaller harvests in recent years. The largest reported harvest occurred in 1990 when 1.2 million pounds were harvested in South Sound. The second largest harvest since establishment of the disposal site was 125,000 pounds in 1994. This is in contrast to the current quota of just 22,000 pounds for the 2015-2016 season, which is 5% of the estimated harvestable biomass (Hank Carson, pers. comm. 2016).

An assessment that the decline in abundance of sea cucumbers is the result of over-harvesting needs to be tempered by several caveats (Hank Carson, pers. comm. 2016). First, the large harvests reported in the early 1990s occurred before quotas were used in fishery management of this species. Second, harvest quotas have not always been directly related to abundance. So, while the harvest has averaged approximately 30,000 pounds per year since 1994, this number does not necessarily reflect the actual abundance of sea cucumbers in South Sound during that period. It is important to note though that the current quota of 22,000 pounds is indeed related to abundance, representing 5% of the estimated harvestable biomass. Third, it is not certain that intensive harvest of sea cucumbers from certain habitats or depths necessarily reduces the density in other habitats or depths outside of the harvest area (Hank Carson, pers. comm. 2016; Carson 2015).

4.1.4 Sea Stars

Sea stars were generally evenly distributed throughout the study area during the 1987 siting study, with the highest densities at stations along Transect 1 and off the southwest shore of Anderson Island. In 2014-2015 sea stars were somewhat less evenly distributed, with high concentrations found in May and October at the south stations of Transect 2 and in October at the outer boundary of Oro Bay. Similar to 1987, stations off the southwest shore of Anderson Island again had higher-than-average densities of sea stars. In contrast, stations along Transect 1 had lower densities of sea stars in 2014-2015 compared to 1987. During the 1987 siting study, sea stars were approximately 30% less abundant (178 individuals/ha) than in 2014-2015 (236 individuals/ha).

The health and abundance of sea stars have gained more interest in recent years due to a recent west coast outbreak of a densovirus causing what has become known as “sea star wasting disease.” Though sea star wasting disease has been documented for at least 30 years (Bates et al. 2009), the prevalence of this disease in the northeast Pacific increased dramatically in June 2013 (Schrope 2013). The 2013-2014 outbreak was extensive in California, Oregon, Washington, and British Columbia. Causes of the outbreak are unknown, but a recent collaborative effort indicated that the mass mortalities were correlated with the presence of a densovirus in the tissues of affected sea stars (Hewson et al. 2014). This disease is prevalent in Puget Sound, and was detected in some individuals throughout the 2014-2015 study, although healthy juveniles were also detected in each quarterly sampling event. The effect of sea star wasting disease on the abundance of sea stars within the area of investigation during the 2014-2015 study is unknown. Data from the study demonstrate an increase in sea star abundance between 1987 and 2014-15. This suggests that currently the effect of the disease on South Sound sea stars may not be significant.

4.1.5 Other Invertebrates

A variety of other invertebrates that do not support sport or commercial harvest were captured in both surveys. Due to the relative absence of their discussion in the 1987 siting study, it is not possible to compare the two data sets. However, during the 2014-2015 study, well over 50 epibenthic invertebrate species, including anemones, nudibranchs, shrimp and crab, were captured.

4.1.6 Fish

It was not possible to compare the fish capture data from the 2014-2015 beam trawl study to the otter trawl data from the 1987 investigations. While the beam trawl is effective for sampling epibenthic invertebrates, it is a far less suitable tool for capturing demersal fish. However, nearly 50 species of fish were captured over the course of the 2014-2015 beam trawl study, with fish being captured at each of the 38 sites. Some species, such as blackbelly eelpouts, roughback sculpin and plainfin midshipman were widespread and prolific, whereas others such as gunnels, pipefish, and flatfish were likely much more habitat- or depth-dependent occurrences.

One pre-survey concern of the 2014-2015 study team was the need to avoid capture of fish listed under the Endangered Species Act (ESA), notably salmonids and rockfish. The use of a beam trawl minimized the risk of capturing an ESA-listed fish, whereas use of an otter trawl would have presented a greater risk. Prior to initiating the 2014-2015 study, biologists from the National Marine Fisheries Service concurred that it was highly unlikely that a beam trawl would capture these species. After successfully completing more than 150 beam trawl tows, the research team was pleased to report that no ESA-listed fish were captured during the course of the 2014-2015 study.

Concurrent with the summer of 2014 beam trawling effort, the Washington Department of Fish and Wildlife conducted a Remotely Operated Vehicle (ROV) study at many of the same target locations. Although ROV surveys can also experience challenges with fish avoidance, these surveys are helpful for detecting fish not recorded using other sampling methodologies, and also providing a better description of underwater habitat in a given location of interest. The ROV study report is forthcoming (Pacunski, pers. comm. 2015).

4.2 On-site vs. off-site

Another principal goal of the 2014-2015 study was to compare the demersal resources at stations within the Anderson/Ketron Island disposal site boundary to resources at off-site stations. This was especially important for invertebrate species of potential interest to recreational or commercial fisheries, including Dungeness and red rock crab, Pandalid shrimp and sea cucumbers.

4.2.1 Crab

A comparison of crab populations at on-site stations to those at off-site stations yielded results for the 2014-2015 study that were similar to the 1987 study. Both studies found few, if any, Dungeness crabs at on-site stations. In 1987, no Dungeness crabs were found at the single on-site station in any season. In 2014-2015, a total of only two Dungeness crabs were found at the eight on-site stations over all seasons. Neither of these was a legal male. One was an adult female collected from station S-2 in May and the other a juvenile male collected at EW-4 in July.

There were a number of off-site stations in both studies that had higher densities of Dungeness crabs than on-site stations. In 1987, densities above 50 crabs/ha were reported at two off-site stations (T02-60S in February and T03-10S in July). There were no stations that year with densities above 100 crabs/ha. In 2014-2015, densities above 50 crabs/ha were reported at off-site stations five times (at three stations in February, and one station each in May and July). Densities above 100 crabs/ha were reported three times (station T03-20N in February; station T02-80S in May and July). However, of the stations with densities greater than 100 crabs/ha, none had any adult males of legal size. All Dungeness crabs collected at T03-20N in February were juveniles and all Dungeness crabs collected at T02-80S in May and July were adult females.

Because the 1987 siting study did not differentiate between red rock crabs and graceful *Cancer* crabs on a station-specific basis, it is not possible to compare on-site to off-site stations for red rock crab alone. For red rock crabs and graceful *Cancer* crabs combined, quarterly densities at the single on-site station (ZSF 2.2) in 1987 were very low, with a density of 19 crabs/ha in February, May and July; and 75 crabs/ha in October (Appendix B). The mean of these quarterly densities at this station was 33 crabs/ha (Table 4). In contrast, the mean quarterly density at 16 of the 29 off-site stations exceeded 33 crabs/ha in 1987, ranging as high as 155 crabs/ha at T03-10S (Table 4). The highest quarterly density at an off-site station in 1987 also occurred at T03-10S, with a density of 487 crabs/ha in October (Appendix B).

In the 2014-2015 study, the combined mean quarterly density of red rock crabs and graceful *Cancer* crabs at the same on-site station studied in 1987 (ZSF 2.2) was 34 crabs/ha, which is approximately the same as the 33 crabs/ha found at that station in 1987 (Table 4). Quarterly densities at this station ranged from zero in May and October, to a high of 103 crabs/ha in July (Appendix B). The mean density of combined red rock crabs and graceful *Cancer* rock crabs over all eight on-site stations for all seasons in 2014-2015 was 154 crabs/ha, with mean quarterly densities at individual on-site stations ranging from 17 crabs/ha at EW-1 to 908 crabs/ha at EW-3 (Table 4). This latter station is at the center of the disposal site, where debris was encountered during trawling. A possible explanation for the higher densities at EW-3 is that the shell, rock and other debris found there provided favorable habitat for "rock crab", thus attracting larger numbers of these species to this station than to other on-site stations. The mean quarterly density of combined red rock crabs and graceful *Cancer* crabs at the seven other on-site stations was only 52 crabs/ha. With regard to the off-site stations, the mean quarterly density of combined red rock crabs and graceful *Cancer* crabs at 23 of the 30 off-site stations exceeded the mean quarterly density of 154 crabs/ha at the eight on-site stations in 2014-2015 (Table 4). If EW-3 is excluded as an outlier, all but two off-site stations exceeded the mean quarterly density of 52 crabs/ha found at the seven other on-site stations. The highest mean quarterly density at an off-site station in 2014-2015 was 2,145 crabs/ha at T01-80W (Table 4). This station also had the highest quarterly density, with 3,466 crabs/ha in July (Appendix B).

Since the 2014-2015 study differentiated between species of "rock crab", it is possible to evaluate red rock crab alone. Like Dungeness crabs, red rock crabs (*Cancer productus*) were scarce on-site when compared to off-site stations (Figure 33). A total of seven *C. productus* individuals were captured on-site in 2014-2015 over all seasons, yielding a mean quarterly density of 7.3 red rock crabs/ha. In contrast, mean quarterly densities at 22 of the 30 off-site stations exceeded this mean quarterly on-site density (Table 5). By far the highest mean quarterly density at an off-site station in 2014-2015 occurred at T02-60S, with 723 red rock crabs/ha. The highest quarterly density also occurred at T02-60S, which had 2,109 red rock crabs/ha July (Table 5). It is apparent from Figure 33 that *C. productus* was found in greater numbers at the shallow to mid-depth stations and occurred in low numbers at the deeper stations, including those within the disposal site.

4.2.2 Pandalid Shrimp

Pandalid shrimp densities were generally much higher at off-site stations in 2014-2015, especially for the larger species targeted by recreational shrimpers, such as *Pandalus platyceros* (spot prawns) and *P. hypsinotus* (coonstripe shrimp). The vast majority of Pandalid shrimp found at on-site locations in 2014-2015 were the much smaller pink shrimp (*P. jordani* and *P. eous*), of little potential interest for a commercial fishery at the densities found, and of little or no recreational value. As indicated earlier, Pandalid shrimp were much more abundant at the on-site stations in 2014-2015 when compared to the 1987 study, during which there were no Pandalids whatsoever found at the single on-site station, ZSF 2.2 (Table 6). This on-site increase was due, in large part, to increases in *P. jordani* and *P. eous*.

The mean Pandalid shrimp density in 2014-2015 at the eight on-site stations over all seasons was 924 shrimp/ha (Table 6). On a seasonal basis, the highest mean on-site density was 1,970 Pandalids/ha in July, followed by May with 1,353 Pandalids/ha. The lowest mean on-site densities occurred in February and October, with 116 and 255 Pandalids/ha respectively.

Pandalid shrimp densities were much higher at the 30 off-site stations. The mean density over all off-site stations and seasons was 5,131 Pandalids/ha (Table 6), ranging from a low of 2,792 Pandalids/ha in May to 7,616 Pandalids/ha in October (Appendix B). In contrast to the on-site stations, *P. danae* was often the most abundant species of Pandalid shrimp at the off-site stations, with densities as high as 67,096 shrimp/hectare at station T02-60N in October.

4.2.3 Sea Cucumber

In 2014-2015, a single California sea cucumber (*Parastichopus californicus*) was collected within the Anderson/Ketron disposal site boundary, at station ZSF 2.2 in July. This was similar to the 1987 study, in which sea cucumbers were found at the single on-site station (ZSF 2.2) in only two of the four seasons (May and October). The exact number was not included in any of the 1987 study reports (Dinnel et al. 1987a,b,c,d,e; Dinnel et al. 1988), but densities in those two months were in the 1-100 individuals/ha range (Figure 30).

Sea cucumbers occur in higher densities on hard substrates such as bedrock and boulders, in intermediate densities on cobble, pebble, and shell, and in lower densities on soft substrate such as sand and mud (Carson et al., 2016). So the low density of *P. californicus* at the on-site stations is what would be expected on the soft substrates found over most of the disposal site. The non-dispersive Anderson-Ketron Island disposal site was intentionally placed in a depositional area where fine-grained particles tend to settle out to form a soft-bottom substrate. Coarser grained dredged material tends to come to rest shortly after contacting the bottom after disposal. Therefore, the center of the disposal site has a harder substrate than what existed prior to establishment of the site. However, finer grained dredged material spreads laterally following disposal, maintaining a soft substrate over the majority of the site.

Densities at off-site stations were highly variable in both studies, with the highest concentrations of sea cucumbers found at shallow-water stations. The high variability is consistent with *P. californicus's* preferred habitat of boulders, cobbles and gravel which tends to occur in highly localized areas in South Sound (Hank Carson, pers. comm. 2016). The mean quarterly density over all 30 off-site stations in 2014-2015 was 89 individuals/ha, with the highest mean quarterly density being 736 individuals/ha at T02-20S. The highest quarterly density in 2014-2015 at an off-site station was 1,304 individuals/ha, occurring in May at T02-20S. As discussed previously, sea cucumbers were more abundant in 1987. The mean quarterly density over all 29 off-site stations in 1987 was 173 individuals/ha, with the highest mean quarterly density being 1,096 individuals/ha at T02-80S. The highest quarterly density in 1987 at an off-site station was 1,816 individuals/ha, occurring in October at T02-80S.

4.2.4 Sea Stars

In 2014-2015, sea star density was relatively low at the eight on-site stations. The mean quarterly on-site density was just 13 individuals/ha. The 1987 study yielded similar results, with a mean quarterly density of 10 individuals/ha at the single on-site station (ZSF 2.2). Densities at off-site stations were higher in both studies, with a mean quarterly off-site density of 263 individuals/ha in 2014-2015 and 184 individuals/ha in 1987.

4.3 Comparison of on-site results to commercially viable thresholds

During the 1987 PSDDA siting study, attention was focused on “invertebrate species of actual or potential commercial and sport concern.” This included Dungeness crab, “rock crab” (red rock crab and graceful rock crab combined), Pandalid shrimp and sea cucumbers. Washington Department of Fisheries criteria were utilized as indicators of commercially viable densities of crab. A Dungeness crab density of 100 crabs/hectare or less was considered to have a minimal impact on the potential for commercial or recreational harvesting of this species (PSDDA, 1989). Similarly, densities of less than 250 Pandalid shrimp/hectare were considered to be of minimal importance for a potential fishery (David Kendall, pers. comm. 2014). The following sections compare on-site results from the 2014/2015 trawl study against these criteria and also provide a qualitative assessment of the commercial viability of the various species of Pandalid shrimp in today’s market. Harvesting of sea cucumbers is briefly discussed. The 1987 study results are included for reference.

4.3.1 Dungeness Crab

The mean density of Dungeness crabs in 2014-2015 over all eight on-site stations and seasons was only 1.1 crabs/ha, well under the 100 crabs/ha threshold used in 1987 to determine a Dungeness crab population of potential commercial or recreational value. The highest quarterly on-site density in 2014-2015 was 2.2 crabs/ha in both May and July. In 1987, no Dungeness crab were found at the single on-site station (ZSF 2.2) in any quarter.

Some stakeholders have contended that dredged material disposal has impacted the Dungeness crab population in the vicinity of the Anderson/Ketron Island disposal site. Results from the study indicate that the number of Dungeness crabs has increased by a factor of 2.5 from 1987 to 2014-2015. The study also showed that Dungeness crabs were scarce within the disposal site boundary in 2014-2015, just as they had been in 1987. Thus, the study provided evidence that the dredged material disposal site had been located properly in an area with few biological resources and that the Dungeness crab population in the vicinity of the site had not been impacted by use of the site.

The conclusion that dredged material disposal has not impacted the Dungeness crab population in the vicinity of the site is supported by catch records compiled by WDFW. Table 10 and Figure 34 show the catch records compiled for Marine Area 13 for the last 11 years. Dredged material disposal events at the Anderson/Ketron Island site have been added to the table and figure for reference. As can be seen from the table and figure, dredged material disposal has occurred during both an uptrend in Dungeness crab harvest and a downtrend. Following the largest disposal event at the site, which occurred in 2007, harvests increased significantly over the next three years. The next disposal event occurred in 2012, the same year in which a peak harvest was recorded. The Dungeness harvest declined the next three years, including in 2014 when the last disposal event occurred.

4.3.2 Red Rock Crab

The mean density of red rock crabs (*Cancer productus*) in 2014-2015 over all eight on-site stations and seasons was 7.3 crabs/ha. The quarterly on-site density in 2014-2015 ranged from zero in February to 15.1 crabs/ha in May. If the commercial viability density of 100 crabs/ha used for Dungeness crab in 1987 is applied to red rock crab, it can be seen that the densities found at the on-site stations in 2014-2015 are far below this criteria. Although *C. productus* has become an important component of the MA 13 recreational crab fishery and, recently, Treaty commercial red rock crab fisheries have been suggested in South Sound (Don Rothaus, pers. comm. 2016), the low numbers found at the disposal site would presumably make the site unattractive to sport and Treaty crabbers. Tabular catch data for *C. productus* were not available for 1987 so no direct comparison can be made.

4.3.3 Pandalid Shrimp

Separate evaluations are required for commercial and recreational fisheries. Recreational shrimpers are generally only interested in the larger Pandalids, not the much smaller Alaskan and smooth pink shrimp. Commercial shrimpers are potentially interested in pink shrimp, in addition to the larger Pandalids.

It is important to note that the commercial viability threshold used for Pandalid shrimp in 1987 does not reflect the reality of today's market in which the value of shrimp is largely species-dependent. For example, spot prawns are far more valuable than pink shrimp (Don Velasquez, pers. comm. 2016). Thus, use of a single density parameter for combined Pandalid shrimp species is of limited utility and is, therefore, accompanied by additional discussion.

Recreational: Figures 35-38 show the seasonal densities of the Pandalid shrimp of recreational interest (*Pandalus danae, P. hypsinotus, P. platyceros, P. tridens and Pandalopsis dispar*) collected in 2014-2015. These species have been combined to better display the full recreational potential at each station. The density of Pandalid shrimp of recreational interest averaged over all the on-site stations and seasons was 36 shrimp/ha. Quarterly means ranged from a low of 8 shrimp/ha in February to 119 shrimp/ha in July. All quarterly means were below the threshold of 250 shrimp/ha used in 1987. Densities at individual on-site stations exceeded the threshold only once, reaching 500 shrimp/ha at EW-1 in July. However, five of the eight on-site stations had no recreational Pandalids found in July, bringing the on-site mean well below the 250 shrimp/ha threshold.

Some significant recreational catches of spot prawns did occur in 2015 from south Puget Sound, including areas in Carr Inlet, near Oro Bay, and adjacent to Ketron Island. This may represent an improvement in densities of *P. platyceros* compared to the situation described by Magoon in 1979 (Magoon and Bumgarner, 1979) (Don Velasquez, pers. comm. 2016). However, on-site densities of spot prawns were low compared to other stations within the study area, presumably making the disposal site itself unattractive to recreational shrimpers.

Commercial: Any commercial interest in Pandalid shrimp is likely to focus on the spot prawn, *Pandalus platyceros* (Don Rothaus, pers. comm. 2016). Spot prawns were found at only a small number of stations during the 2014-2015 study and typically at low density. Spot prawn densities averaged over the entire study area ranged from a low of 11.8 shrimp/ha in July to a high of 64.7 shrimp/ha in February. Densities greater than 250 shrimp/ha were reported at only one station in each of the seasonal surveys. The only spot prawns collected within the Anderson/Ketron Island disposal site boundary were at station EW-1 in July, at a density of 65 shrimp/ha. Spot prawns were not collected on-site at any other station or in any other season. At present, neither State nor Treaty commercial fisheries exist in Management Area 13 and would likely not be supported by the spot prawn densities found in the 2014-15 trawl study (Don Rothaus, pers. comm. 2016). Forays into Marine Area 13 made by State-licensed commercial pot fishers prior to establishment of the Anderson-Ketron Island disposal site in 1989 were met with very little success, and as a result there has been very little commercial interest in this area (Don Velasquez, pers. comm. 2016).

The potential for a commercial pink shrimp fishery in this area is also unlikely. Pink shrimp are generally commercially harvested using trawl gear. They are a low value species (approximately $0.25 to $0.35/pound) and require huge volumes in order to be cost effective. Even at some of the higher densities seen in this study, it is not likely that a trawl fishery would be supported (financially or environmentally) in South Puget Sound (Don Rothaus, pers. comm. 2016). Other parts of Puget Sound that are harvested commercially have higher densities than those found in the 2014-2015 study and cover larger areas (Don Velasquez, pers. comm. 2016).

4.3.4 Sea Cucumbers

Sea cucumbers are harvested by divers only. Due to the logistics of diving, harvest is generally restricted to water shallower than -100 ft MLLW (Hank Carson, pers. comm. 2016). Harvesters decrease their risk of decompression sickness and spend more time harvesting by avoiding deeper water (Carson et al., 2016). The Anderson-Ketron Island disposal site is much deeper than this and is, therefore, unsuitable for harvesting. Even without this restriction, the very low density of sea cucumbers at on-site stations would make the disposal site unattractive for harvesting.

4.4 Conclusions

The 2014-2015 trawl study was conducted to address stakeholder concerns regarding the continued use of the Anderson/Ketron Island dredged material disposal site. The study replicated the epibenthic portion of the demersal resource evaluation conducted during the original PSDDA siting study in 1987. The objectives of the study were threefold: 1) evaluate the epibenthic biological resources in the vicinity of the disposal site for any important changes that may have occurred since 1987; 2) compare the existing epibenthic invertebrate community between off-site and on-site stations; and 3) compare densities of invertebrate species at on-site stations to the thresholds for commercial or recreational viability used during the 1987 siting study. The following sections present the conclusions of this study with respect to these three objectives for invertebrate species of actual or potential commercial and sport concern. The professional opinions of WDFW staff members are also provided. Table 11 provides a general summary of study findings. The implications of study findings for the continued use of the Anderson-Ketron Island site are also discussed.

4.4.1 Dungeness Crab

Dungeness crab (*Cancer magister*) were more abundant in 2014-2015, with wider distribution, than in 1987. There were approximately 2.5 times more Dungeness crabs captured during the 2014-2015 study. However, the mean density of Dungeness crabs was very low in 1987, so the increase in abundance was in comparison to a very low benchmark. Also, the increase in abundance was not across all sex and size categories. The overall densities of legal males were essentially the same in the two studies. Furthermore, despite the overall greater abundance, Dungeness crab were still scarce within the boundary of the Anderson-Ketron Island disposal site. There were no *C. magister* found during either study at the single on-site station common to both studies (ZSF 2.2) and only two individuals were captured at the other seven on-site stations over the entire course of the 2014-2015 study, neither of which was a legal-size male. The quarterly on-site densities of Dungeness crabs in 2014-2015 (ranging from zero in February and October to 2.1 crabs/ha in May and July) were far below the 100 crabs/ha threshold used during the 1987 siting study as an indicator of viability for a recreational or commercial crab fishery.

In conclusion, there is nothing in the 2014-2015 study that indicates that use of the Anderson-Ketron Island disposal site has had any adverse impact on Dungeness crab or that the viability of the site for dredged material disposal has changed since 1987.

4.4.2 "Rock Crab"

"Rock crab" were much more abundant in 2014-2015 than during the 1987 siting study. In 1987, station-specific densities were relatively uniform throughout the study area, without obvious concentrations at any of the stations (Figure 10). In contrast, in 2014-2015 the density of "rock crabs" at some stations was much higher than at others (Figure 9). "Rock crab" densities at the single on-site station (ZSF 2.2) in 1987 ranged from 19-75 crabs/ha over the four seasons. The seasonal "rock crab" densities at this same station in 2014-2015 were similar, ranging from zero to 103 crabs/ha (Appendix B). The vast majority of "rock crabs" captured in 2014-2015 were *Cancer gracilis*, which comprised approximately 85% of the population. *Cancer productus* was relatively scarce. Because the 1987 study did not include data tables that differentiated between species, it was not possible to compare results between the two studies in a detailed way. In general, it can be concluded that a significant increase in "rock crab" numbers occurred within the study area between 1987 and 2014-2015. Also, a crude estimate of the change in the *C. productus* population can be calculated using the fraction of red rock crab provided in Dinnel et al. 1988 (10%) and the fraction found in the 2014-2015 study (15%). Using these number, the average density of C. productus increased about ten-fold between 1987 and 2014-2015. However, despite the overall increase in "rock crab" numbers within the general study area, no important change occurred in "rock crab" numbers at the single on-site station shared by the two studies.

With the exception of EW-3 at the center of the disposal site, the "rock crab" densities at on-site stations in 2014-2015 were relatively low compared to those at off-site stations. Excluding EW-3, the mean on-site "rock crab" density averaged over all stations and seasons was only 46 crabs/ha, compared to 449 crabs/ha averaged over all off-site stations. The results at EW-3 were much different than at other on-site stations, with a mean density of 908 crabs/ha averaged over all seasons. This is likely the result of debris found at this station during the study, which provides more habitat for "rock crab". Debris found at EW-3 included naturally occurring material (e.g. shell hash and rock) as well as anthropogenic debris (e.g. cable and construction material). Almost all "rock crab" found at on-site stations were *Cancer gracilis,* with *Cancer productus* almost completely absent from on-site stations in 2014-2015 (Figures 11-14). Assuming that EW-3 is not representative of the majority of the disposal site, it can be concluded that the on-site density of "rock crab" is significantly less than the off-site density of "rock crab". Even without this assumption, it can be concluded that the on-site density of *C. productus* was considerably lower than the off-site density.

Due to the small size of *Cancer gracilis*, there is little potential for sport or commercial harvest of this species and current rules prohibit its harvest (Don Velasquez, pers. comm. 2016). Even if harvest was allowed, its small size limits the meat yield per individual making them unattractive to most potential harvesters. *Cancer productus*, because of its larger size, has become an important component of the MA 13 recreational crab fishery and, recently, Treaty commercial red rock crab fisheries have been suggested in South Sound (Don Rothaus, pers. comm. 2016). The quarterly on-site densities of *C. productus* in 2014-2015 (ranging from zero in February to 15 crabs/ha in May; Table 5) were far below the 100 crabs/ha threshold used during the 1987 siting study as an indicator of the viability of Dungeness crab for a recreational or commercial crab fishery. Even when combined with Dungeness crabs, the density of harvestable crabs (*C. magister* + *C. productus*) at the on-site stations was still below 20% of the viability threshold in all seasons.

In conclusion, there is nothing in the 2014-2015 study that indicates that the viability of the Anderson-Ketron Island site for dredged material disposal has changed since 1987, at least with regard to *Cancer productus*. Given the concentration of *C. gracilis* at the site center, it can be concluded that some individuals of this species are likely to be impacted during dredged material disposal events. While some level of mortality is probable, crab are also highly mobile and capable of digging up through sediment. However, the levels of avoidance, escape or mortality cannot be predicted from the results of this study.

The presence of debris at the center of the site – which apparently serves as habitat for *C. gracilis* – reinforces the DMMP agencies' recent change in debris management procedures. The revised procedures (DMMP, 2015) require the use of a 1-ft by 1-ft grid to remove larger debris from the dredged material prior to disposal if there is a reason to believe that debris is present at the dredge site. Elimination of the placement of larger debris at the disposal site is likely to reduce the attraction of "rock crabs" to the site.

4.4.3 Pandalid Shrimp

Pandalid shrimp were much more plentiful in 2014-2015 than they were in 1987, with approximately 60 times more Pandalid shrimp found in 2014-2015 at the 30 stations common to the two studies. This was primarily due to the presence of large numbers of dock shrimp (*Pandalus danae*) at off-site stations and pink shrimp (*P. jordani* and *P. eous*) at both off-site and on-site stations. During three of the seasonal trawls in 1987, Pandalids were found at fewer than 50% of the stations (Appendix B). In the fourth month (October), Pandalids were collected at 19 of the 30 stations (63%). In 2014-2015, Pandalids were found – on average – at over 80% of these same sites (Appendix B). No Pandalids whatsoever were found at the single on-site station (ZSF 2.2) in 1987. The seasonal Pandalid shrimp densities at this same station in 2014-2015 ranged from 52 to 2,191 shrimp/ha, with a mean of 1,137 shrimp/ha over all seasons (Appendix B). All of the Pandalid shrimp captured in 2014-2015 at ZSF 2.2 were pink shrimp (*P. jordani* and *P. eous*) (Figures 21-24). None of the other Pandalid species were captured at this station. Because the 1987 study did not provide species-specific information in a tabular format and only included low-resolution graphics that summarized results from two trawling methods and over a larger study area, it is difficult to compare results between the two studies on a species-specific basis. However, it can be concluded that a significant increase in the number of Pandalid shrimp occurred within the study area between 1987 and 2014-2015, including at the single on-site station common to both studies.

Densities of Pandalid shrimp at off-site stations in 2014-2015 were over five times greater than at the on-site stations, averaged over all seasons (Table 7). The species composition at on-site vs. off-site stations was also markedly different. Relatively few of the larger Pandalid species were found on-site, where pink shrimp made up the vast majority of the population (Figures 21-24). Shallower off-site stations (0-60 m) had the least diversity, with dock shrimp predominant at these stations (Figures 25-28). Mid-depth off-site stations (60-120 m) had the highest diversity, with dock and pink shrimp present in large numbers, and a significant fraction of coonstripe shrimp (*Pandalus hypsinotus*) and spot prawns (*P. platyceros*) present in February and May. Populations of Pandalids at the deeper off-site stations (> 120 m), were comprised primarily of pink shrimp, similar to the on-site stations. Based on these results it can be concluded that Pandalid shrimp were more plentiful at off-site stations in 2014-2015 when compared to on-site stations. It can also be concluded that species composition is depth-related, with pink shrimp the dominant species at the depths found at the disposal site.

With regard to the potential viability of a recreational fishery for the larger species of Pandalid shrimp within the disposal site boundary, the viability threshold of 250 shrimp/ha used in 1987 was not exceeded in any season (Table 8). Quarterly on-site densities of the larger Pandalid shrimp species ranged from zero in May to 104 shrimp/ha in July.

The potential for a commercial fishery for spot prawns within the disposal site boundary is near zero, with spot prawns having been found at only one on-site station (EW-1) in one season. When only pink shrimp species (*P. jordani* and *P. eous)* are considered, the viability threshold used in 1987 was exceeded in May and July, but not February or October (Table 9). Quarterly on-site densities of pink shrimp ranged from 109 in February to 1,867 shrimp/ha in July. While pink shrimp were the most prevalent of the Pandalids on-site, their densities would not support establishment of a commercial trawl fishery there based on present-day economic and environmental considerations.

In conclusion, there is nothing in the 2014-2015 study that indicates that the viability of the Anderson-Ketron Island site for dredged material disposal has changed since 1987 with respect to the larger Pandalid shrimp species (*Pandalus danae, P. hypsinotus, P. platyceros, P. tridens and Pandalopsis dispar*). With regard to pink shrimp (*P. jordani* and *P. eo*us), on-site densities have increased since 1987, as they have for most of the mid- to deeper-water stations within the area of study. However, pink shrimp are not of interest to sport shrimpers and are not present at densities that would support a commercial fishery.

4.4.4 Sea Cucumber

Only one California sea cucumber (*Parastichopus californicus*) was collected within the Anderson/Ketron disposal site boundary in the 2014-2015 study. Therefore, it can be concluded that there is nothing in the 2014-2015 study with respect to sea cucumbers that indicates that the viability of the Anderson-Ketron Island site for dredged material disposal has changed since 1987.

Table 4. "Rock Crab" (*C. productus* + *C. gracilis*) Densities (crabs/ha) – 1987 vs. 2014-2015

On-Site Stations		
Station	**1987**	**2014-2015**
EW-1	---	25
EW-2	---	100
EW-3	---	908
EW-4	---	65
EW-5	---	17
S-2	---	43
S-3	---	38
ZSF 2.2	33	34
Mean	**33**	**154**

Off-Site Stations		
Station	**1987**	**2014-2015**
ZSF 2.1	5	113
ZSF 2.3	0	22
ZSF 2.4	89	200
ZSF 2.5	24	752
ZSF 2.6	28	570
T01-10E	47	237
T01-20E	47	127
T01-80W	108	2,145
T01-40W	33	1,161
T01-20W	42	322
T01-10W	131	369
T02-10S	89	150
T02-20S	108	352
T02-40S	33	260
T02-60S	28	788
T02-80S	47	654
T02-110	24	829
T02-80N	52	684
T02-60N	66	428
T02-40N	47	234
T02-20N	150	608
T02-10N	103	514
T03-10S	155	696
T03-20S	38	296
T03-40S	19	195
T03-40N	19	149
T03-20N	28	304
T03-10N	19	166
Nisqually D	5	94
S-4	---	42
Mean	**54**	**449**

Table 5. Red Rock Crab (*C. productus*) Densities (crabs/ha): On-Site vs. Off-Site Stations – 2014-2015

On-Site Stations					
Station	**February**	**May**	**July**	**October**	**Mean**
EW-1	0	0	0	0	0
EW-2	0	0	0	0	0
EW-3	0	104	0	43	37
EW-4	0	17	35	0	13
EW-5	0	0	0	0	0
S-2	0	0	0	0	0
S-3	0	0	0	0	0
ZSF 2.2	0	0	34	0	9
Mean	**0**	**15**	**9**	**5**	**7**

Off-Site Stations					
Station	**February**	**May**	**July**	**October**	**Mean**
ZSF 2.1	0	17	0	0	4
ZSF 2.3	0	0	0	0	0
ZSF 2.4	0	0	0	0	0
ZSF 2.5	0	17	16	0	8
ZSF 2.6	0	52	17	0	17
T01-10E	43	0	0	0	11
T01-20E	151	42	0	20	54
T01-80W	22	63	205	0	72
T01-40W	128	190	70	22	102
T01-20W	43	0	227	44	78
T01-10W	65	43	35	86	57
T02-10S	65	210	130	87	123
T02-20S	87	761	173	194	304
T02-40S	303	63	239	328	233
T02-60S	341	248	2109	195	723
T02-80S	17	49	21	0	22
T02-110	0	56	87	0	36
T02-80N	0	106	87	22	54
T02-60N	0	35	22	22	20
T02-40N	0	0	0	0	0
T02-20N	0	61	21	0	21
T02-10N	0	108	22	0	32
T03-10S	0	19	22	0	10
T03-20S	35	35	238	0	77
T03-40S	17	0	0	0	4
T03-40N	0	0	0	0	0
T03-20N	82	104	35	87	77
T03-10N	65	42	31	130	67
Nisqually D	0	0	0	0	0
S-4	0	0	0	0	0
Mean	**49**	**77**	**127**	**41**	**74**

Table 6. Pandalid Shrimp Densities (shrimp/ha) – 1987 vs. 2014-2015

On-Site Stations		
Station	**1987**	**2014-2015**
EW-1	---	568
EW-2	---	750
EW-3	---	1,971
EW-4	---	1,186
EW-5	---	539
S-2	---	491
S-3	---	747
ZSF 2.2	0	1,137
Mean	**0**	**924**

Off-Site Stations		
Station	**1987**	**2014-2015**
ZSF 2.1	5	1,478
ZSF 2.3	9	1,024
ZSF 2.4	33	2,525
ZSF 2.5	33	3,330
ZSF 2.6	9	5,281
T01-10E	417	80
T01-20E	253	359
T01-80W	66	13,772
T01-40W	33	4,100
T01-20W	173	1,831
T01-10W	66	1,384
T02-10S	89	7,896
T02-20S	84	24,025
T02-40S	5	39,437
T02-60S	10	24,974
T02-80S	14	2,561
T02-110	52	5,088
T02-80N	5	10,108
T02-60N	61	2,261
T02-40N	0	11
T02-20N	5	43
T02-10N	543	1,215
T03-10S	5	49
T03-20S	103	409
T03-40S	61	0
T03-40N	225	22
T03-20N	0	32
T03-10N	220	91
Nisqually D	5	116
S-4	---	421
Mean	**89**	**5,131**

Table 7. Pandalid Shrimp Densities (shrimp/ha): On-Site vs. Off-Site Stations – 2014-2015

On-Site Stations					
Station	**February**	**May**	**July**	**October**	**Mean**
EW-1	121	555	1,283	313	568
EW-2	35	2,217	502	245	750
EW-3	258	1,898	5,424	304	1,971
EW-4	52	1,001	3,257	435	1,186
EW-5	104	85	1,757	210	539
S-2	174	1,104	528	157	491
S-3	135	1,861	821	171	747
ZSF 2.2	52	2,101	2,191	205	1,137
Mean	**116**	**1,353**	**1,970**	**255**	**924**

Off-Site Stations					
Station	**February**	**May**	**July**	**October**	**Mean**
ZSF 2.1	433	2,157	2,122	1,200	1,478
ZSF 2.3	433	2,252	995	416	1,024
ZSF 2.4	157	1,542	8,104	296	2,525
ZSF 2.5	433	2,318	7,388	3,183	3,330
ZSF 2.6	2,689	2,442	10,372	5,622	5,281
T01-10E	0	0	0	321	80
T01-20E	130	84	261	959	359
T01-80W	10,697	6,564	32,719	5,109	13,772
T01-40W	1,449	3,651	1,670	9,630	4,100
T01-20W	85	166	1,152	5,921	1,831
T01-10W	0	22	696	4,819	1,384
T02-10S	344	1,869	16,500	12,869	7,896
T02-20S	1,666	2,174	40,580	51,679	24,025
T02-40S	22,907	25,897	41,848	67,096	39,437
T02-60S	15,153	18,033	26,065	40,645	24,974
T02-80S	2,553	3,030	2,643	2,017	2,561
T02-110	3,483	4,254	11,609	1,007	5,088
T02-80N	23,902	4,411	5,326	6,792	10,108
T02-60N	3,022	1,739	216	4,067	2,261
T02-40N	42	0	0	0	11
T02-20N	22	0	86	65	43
T02-10N	22	0	1,341	3,496	1,215
T03-10S	0	0	196	0	49
T03-20S	0	139	1,038	459	409
T03-40S	0	0	0	0	0
T03-40N	0	0	0	87	22
T03-20N	20	0	0	109	32
T03-10N	0	0	15	348	91
Nisqually D	365	0	35	64	116
S-4	0	1,022	470	191	421
Mean	**3,000**	**2,792**	**7,115**	**7,616**	**5,131**

Table 8. Recreational Pandalid Shrimp Densities (shrimp/ha): On-Site vs. Off-Site Stations – 2014-2015

On-Site Stations					
Station	**February**	**May**	**July**	**October**	**Mean**
EW-1	0	0	500	0	125
EW-2	0	0	156	0	39
EW-3	43	0	0	87	33
EW-4	0	0	0	17	4
EW-5	0	0	174	52	57
S-2	17	0	0	0	4
S-3	0	0	0	0	0
ZSF 2.2	0	0	0	0	0
Mean	**8**	**0**	**104**	**20**	**33**

Off-Site Stations					
Station	**February**	**May**	**July**	**October**	**Mean**
ZSF 2.1	0	0	449	0	112
ZSF 2.3	0	0	0	243	61
ZSF 2.4	34	0	574	87	174
ZSF 2.5	0	321	131	522	244
ZSF 2.6	436	2,217	1,170	1,222	1,261
T01-10E	0	0	0	321	80
T01-20E	130	84	261	959	359
T01-80W	8,911	4,849	3,403	957	4,530
T01-40W	1,450	3,651	1,670	9,630	4,100
T01-20W	85	166	1,152	5,921	1,831
T01-10W	0	22	696	4,819	1,384
T02-10S	344	1,869	16,500	12,869	7,896
T02-20S	1,666	2,174	40,580	51,679	24,025
T02-40S	22,907	25,897	41,848	67,096	39,437
T02-60S	15,132	18,033	26,044	40,601	24,953
T02-80S	1,933	2,997	2,643	1,948	2,380
T02-110	411	75	3,043	364	973
T02-80N	2,270	971	1,957	1,622	1,705
T02-60N	805	1,583	216	973	894
T02-40N	42	0	0	0	11
T02-20N	22	0	86	65	43
T02-10N	22	0	1,341	3,496	1,215
T03-10S	0	0	196	0	49
T03-20S	0	139	1,038	459	409
T03-40S	0	0	0	0	0
T03-40N	0	0	0	87	22
T03-20N	20	0	0	109	32
T03-10N	0	0	15	348	91
Nisqually D	0	0	35	64	25
S-4	0	0	0	0	0
Mean	**1,887**	**2,168**	**4,835**	**6,882**	**3,943**

Table 9. Pink Shrimp (*P. jordani* + *P. eous*) Densities (shrimp/ha): On-Site vs. Off-Site Stations – 2014-2015

On-Site Stations					
Station	**February**	**May**	**July**	**October**	**Mean**
EW-1	121	555	783	313	443
EW-2	35	2,217	346	245	711
EW-3	215	1,898	5,424	217	1,939
EW-4	52	1,001	3,257	418	1,182
EW-5	104	85	1,583	158	482
S-2	157	1,104	528	157	486
S-3	135	1,861	821	171	747
ZSF 2.2	52	2,101	2,191	205	1,137
Mean	**109**	**1,353**	**1,867**	**235**	**891**

Off-Site Stations					
Station	**February**	**May**	**July**	**October**	**Mean**
ZSF 2.1	433	2,157	1,673	1,200	1,366
ZSF 2.3	433	2,252	995	173	963
ZSF 2.4	123	1,542	7,530	209	2,351
ZSF 2.5	433	1,997	7,257	2,661	3,087
ZSF 2.6	2,253	225	9,202	4,400	4,020
T01-10E	0	0	0	0	0
T01-20E	0	0	0	0	0
T01-80W	1,786	1,715	29,316	4,152	9,242
T01-40W	0	0	0	0	0
T01-20W	0	0	0	0	0
T01-10W	0	0	0	0	0
T02-10S	0	0	0	0	0
T02-20S	0	0	0	0	0
T02-40S	0	0	0	0	0
T02-60S	21	0	21	44	22
T02-80S	620	33	0	69	181
T02-110	3,072	4,179	8,566	643	4,115
T02-80N	21,632	3,440	3,369	5,170	8,403
T02-60N	2,217	156	0	3,094	1,367
T02-40N	0	0	0	0	0
T02-20N	0	0	0	0	0
T02-10N	0	0	0	0	0
T03-10S	0	0	0	0	0
T03-20S	0	0	0	0	0
T03-40S	0	0	0	0	0
T03-40N	0	0	0	0	0
T03-20N	0	0	0	0	0
T03-10N	0	0	0	0	0
Nisqually D	365	0	0	0	91
S-4	0	1,022	470	191	421
Mean	**1,113**	**624**	**2,280**	**733**	**1,188**

Table 10. 2005 to 2015 Marine Area 13 Dungeness Crab Landings Data

Calendar Year	*Treaty Pounds*	*State Pounds*	*Total Catch*	*Dredged Material Disposal Volume (cy)*
2005	43,623	15,404	59,027	0
2006	12,838	20,662	33,500	0
2007	24,799	16,974	41,773	107,717
2008	14,252	49,906	64,158	0
2009	43,065	55,714	98,779	0
2010	71,153	118,734	189,887	0
2011	117,406	69,200	186,606	0
2012	179,981	64,899	244,880	10,579
2013	90,149	52,185	142,334	0
2014	52,534	43,547	96,081	6,093
2015	16,276	25,165	41,441	0

Source**:** *State Catch Record Card Data and LIFT/TOCAS Treaty Data*
By**:** *D. Rothaus & D. Velasquez (WDFW)*

Table 11. Findings Summary

Biological Resource	***Objective 1*** **Observed Change from 1987 to 2014-2015**	***Objective 2*** **Difference between On-Site Stations and Off-Site Stations in 2014-2015?**	***Objective 3*** **Exceeds the 1987 Commercial/Recreational Viability Threshold On-Site in 2014-2015?**
CANCER CRAB			
Dungeness Crab	2.5 times greater numbers in 2014-2015	Yes; Scarce on-site; more off-site	No
Combined "Rock Crab" (*C. productus* and *C. gracilis*)	Much more abundant in 2014-2015	Yes; Fewer on-site than off-site, except EW-3	No
Red Rock Crab (*C. productus* only)	Approximately 10 times more abundant in 2014-2015	Yes; Scarce on-site; more off-site	No
PANDALID SHRIMP			
All species	Much more abundant in 2014-2015	Yes; Fewer on-site than off-site; Primarily pink shrimp on-site	No (except for Pink Shrimp)
Recreational Pandalid Shrimp (excluding Pink Shrimp)	Much more abundant in 2014-2015	Yes; Scarce on-site; more off-site	No
Pink Shrimp	Much more abundant in 2014-2015	Yes; Found at all deeper-water stations, but more abundant at off-site stations in February and October	Yes; but unlikely commercially viable according to WDFW
ECHINODERMS			
Sea Cucumbers	Only half the number in 2014-2015	Yes; Scarce on-site, more off-site	No
Sea Stars	Roughly equal numbers in both surveys	Yes; Scarce on-site, more off-site	NA

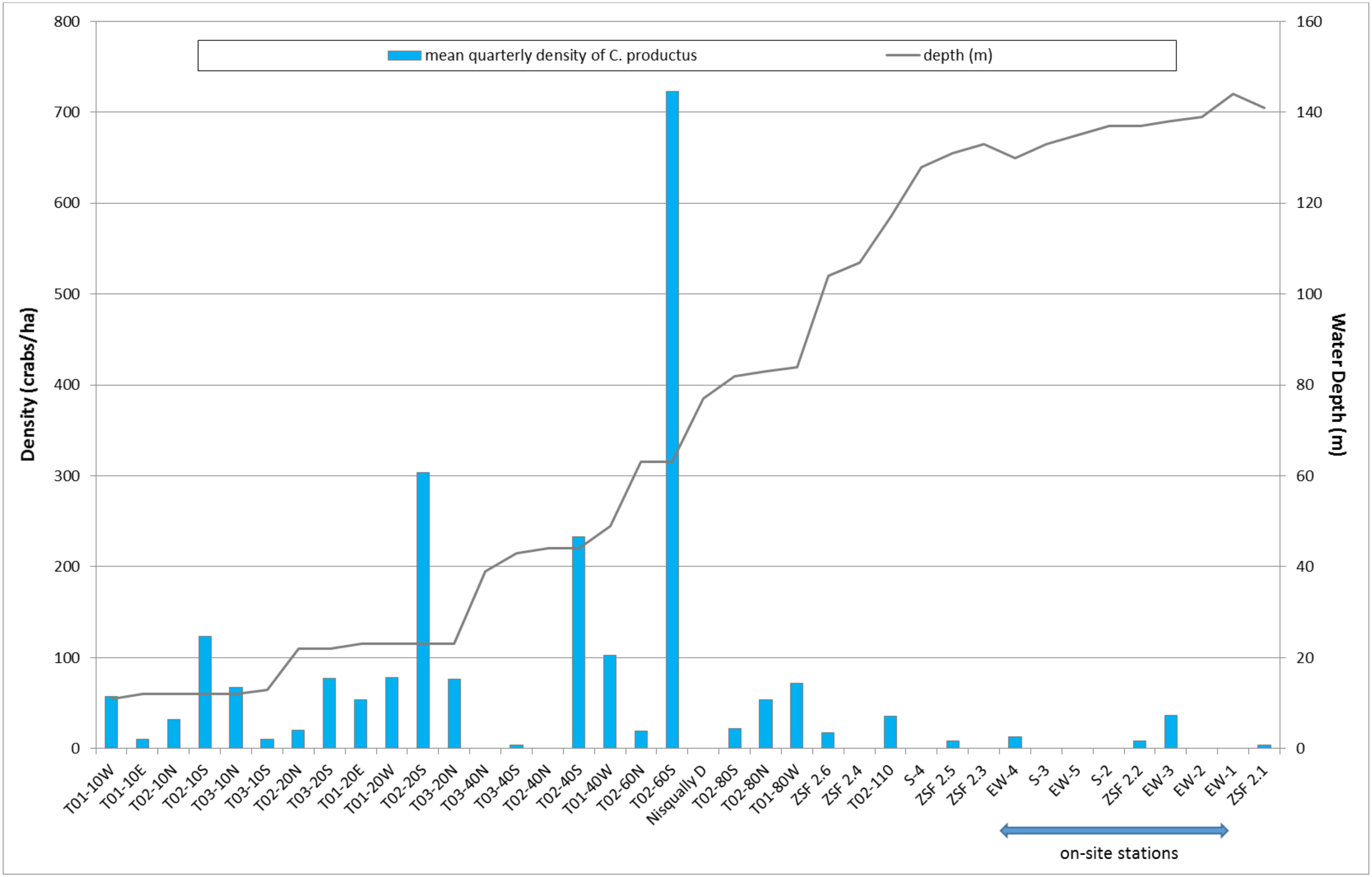


Figure 33. Mean Quarterly Density of Red Rock Crab (*Cancer productus*) in the Vicinity of the Anderson/Ketron site in 2014-2015.

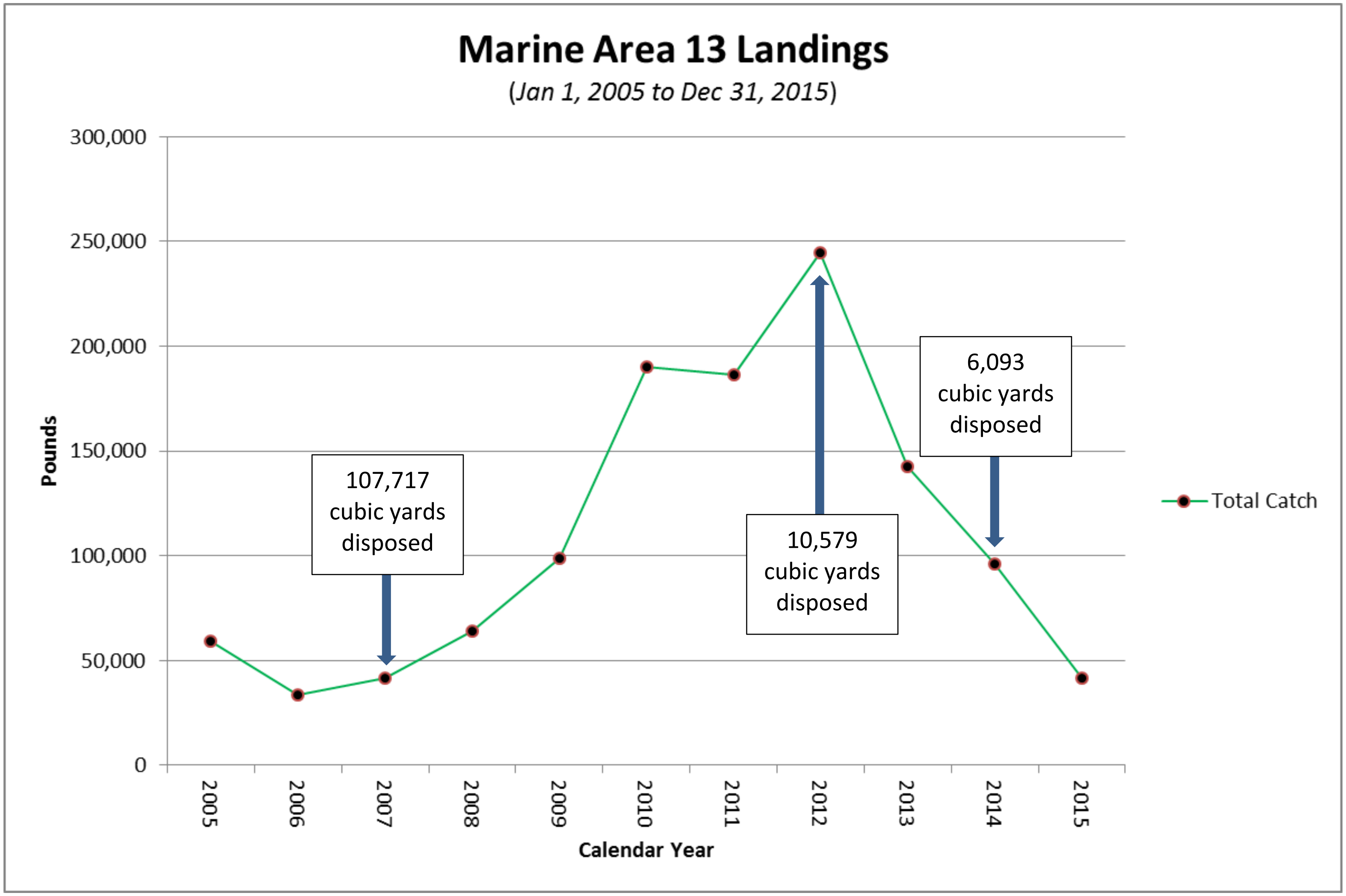


Figure 34. 2005 to 2015 Marine Area 13 Dungeness Crab Landings Data (Treaty, State and Total)

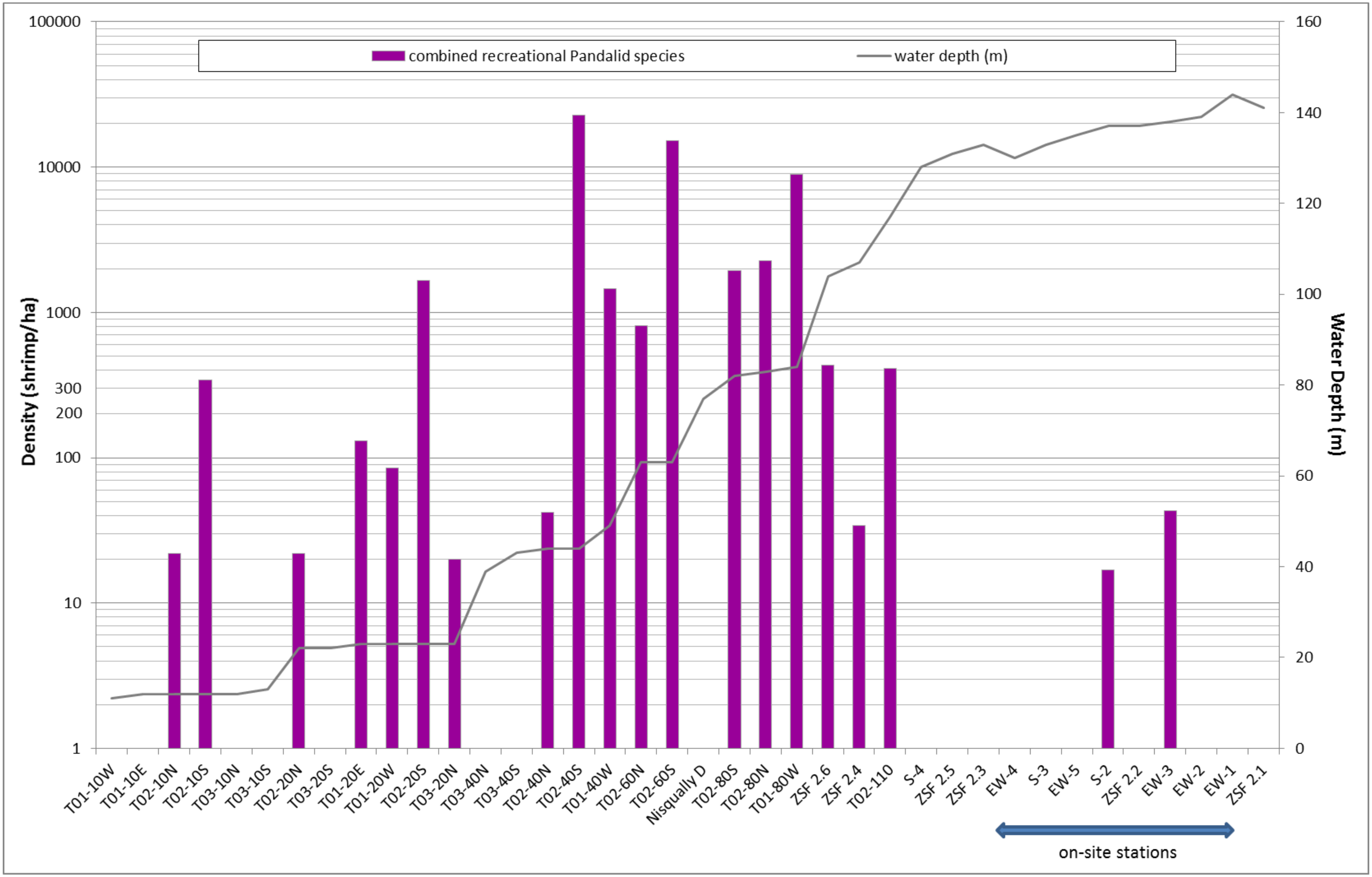


Figure 35. Combined Recreational Pandalid Shrimp Density (log scale) by Depth – February, 2015

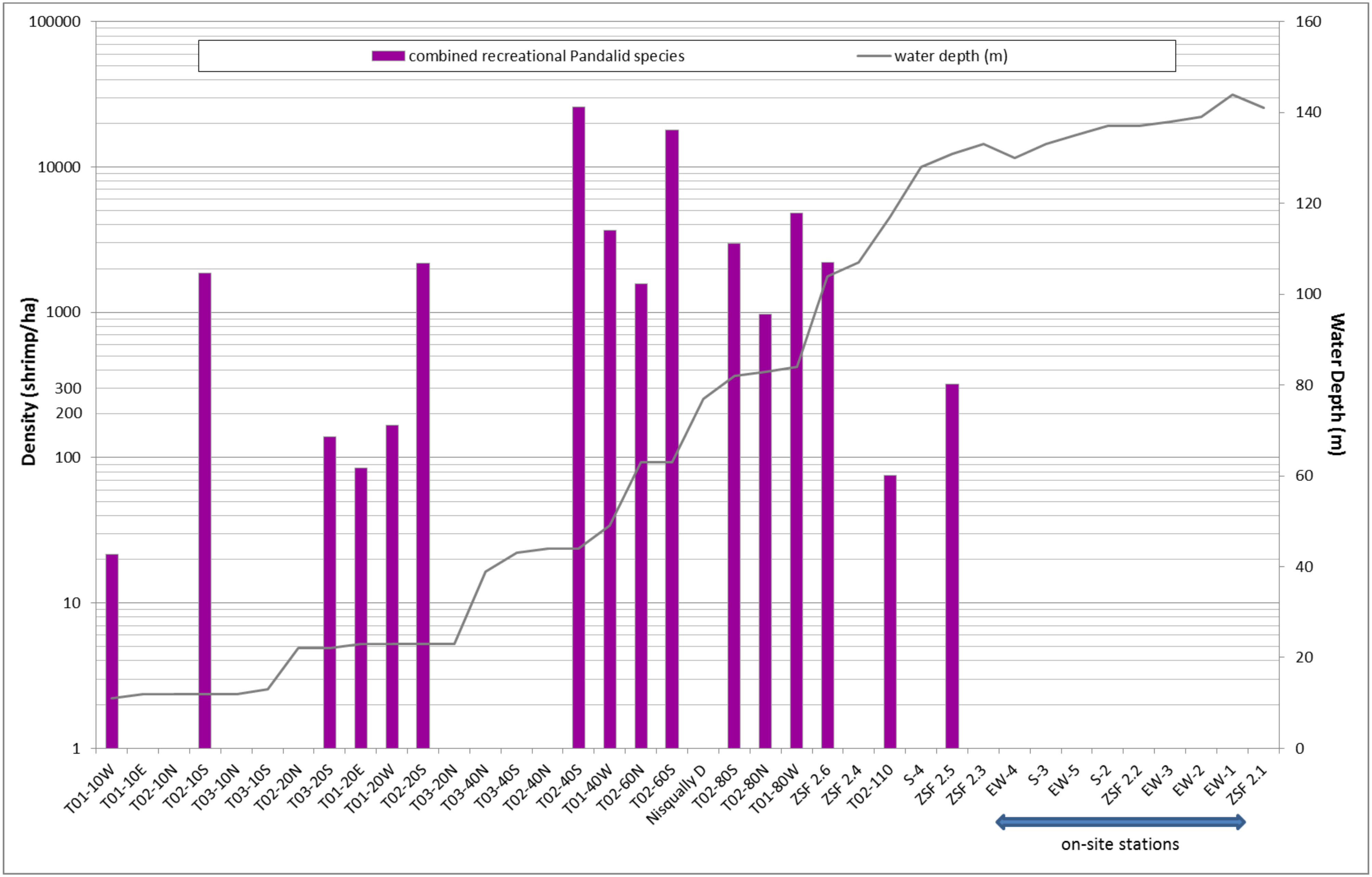


Figure 36. Combined Recreational Pandalid Shrimp Density (log scale) by Depth – May, 2015

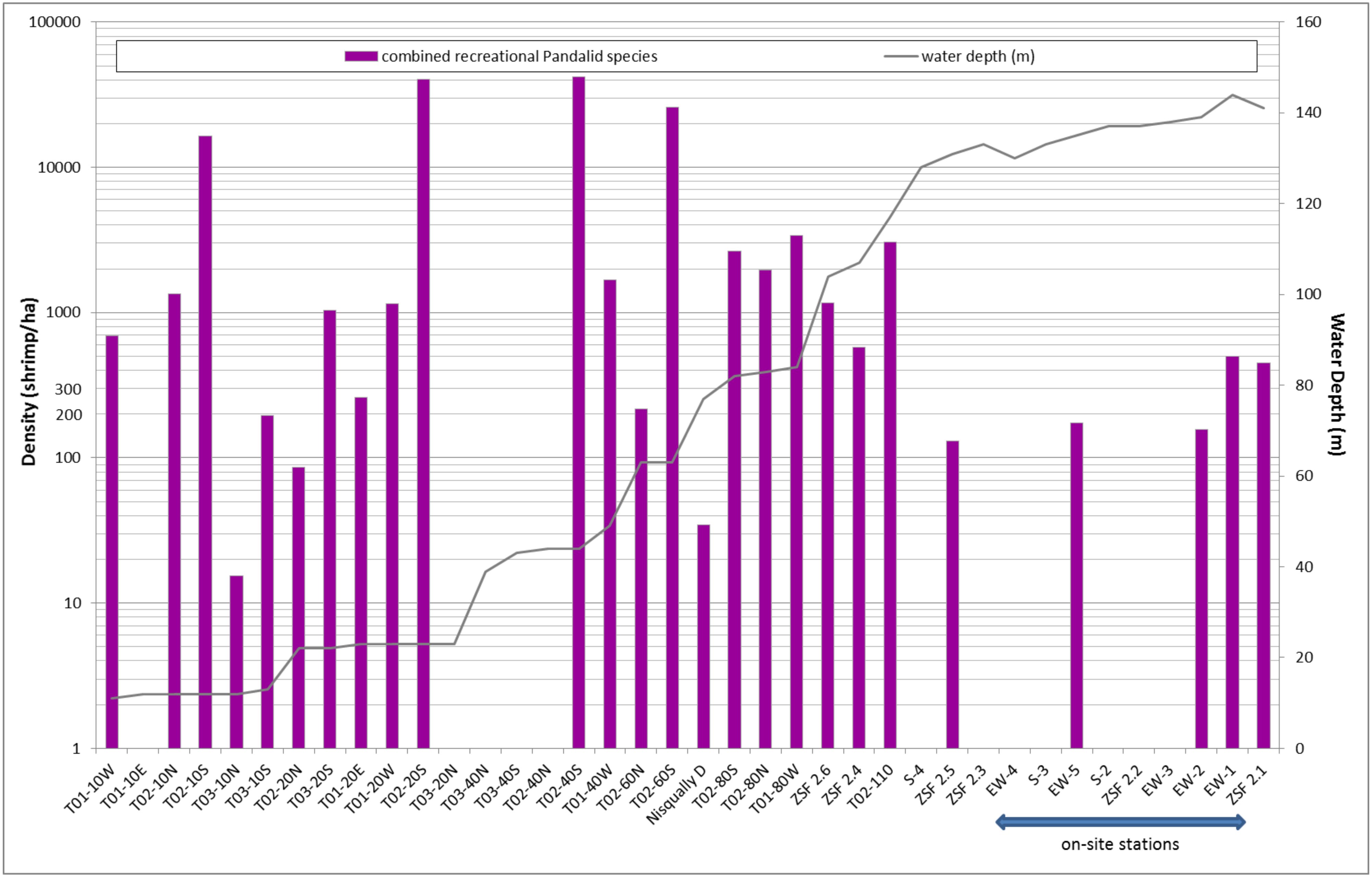


Figure 37. Combined Recreational Pandalid Shrimp Density (log scale) by Depth – July, 2014

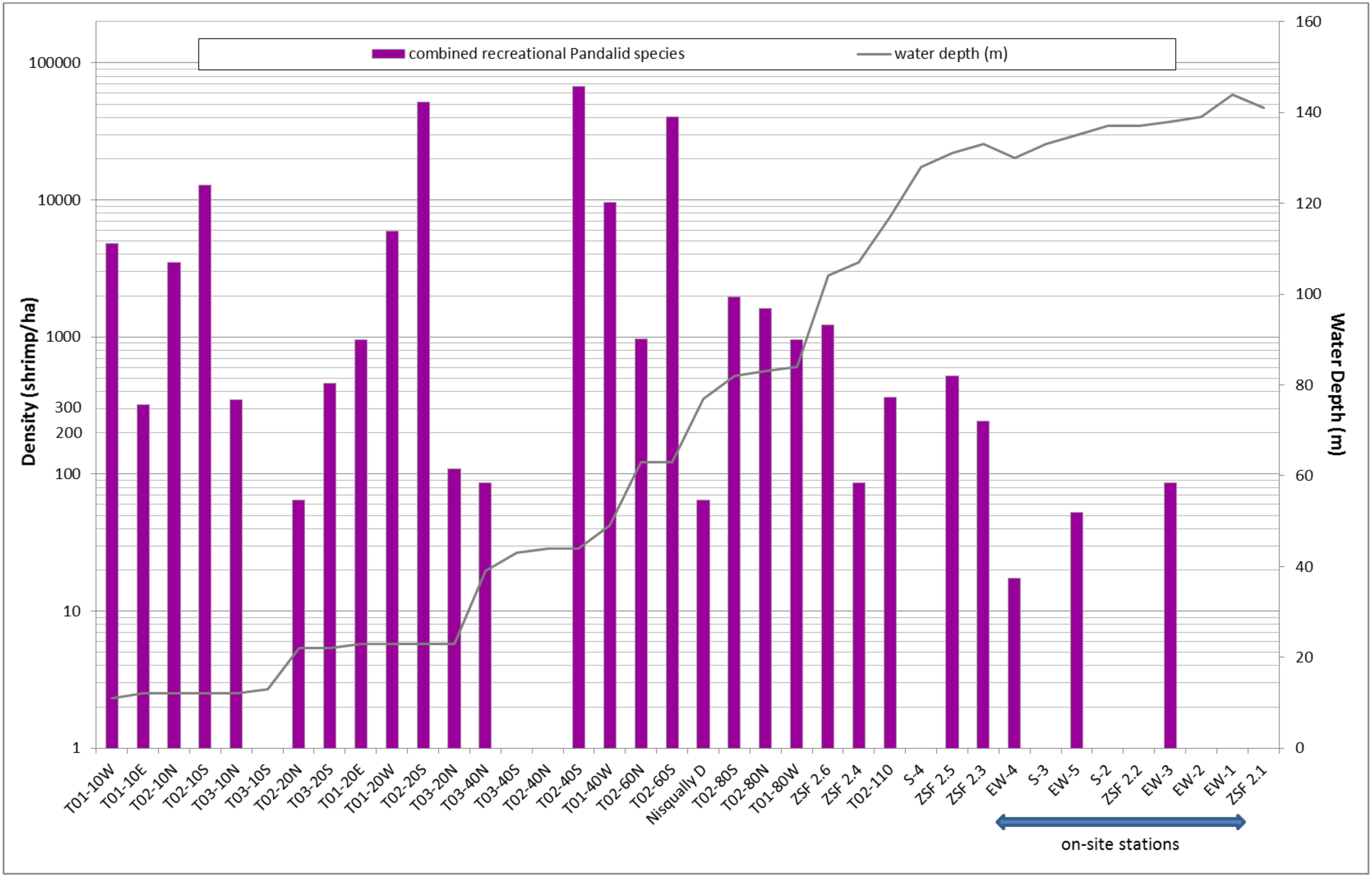


Figure 38. Combined Recreational Pandalid Shrimp Density (log scale) by Depth – October, 2014

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Appendix A

Actual Beam Trawl Survey Track Lines for the 2014-2015 Anderson/Ketron Study

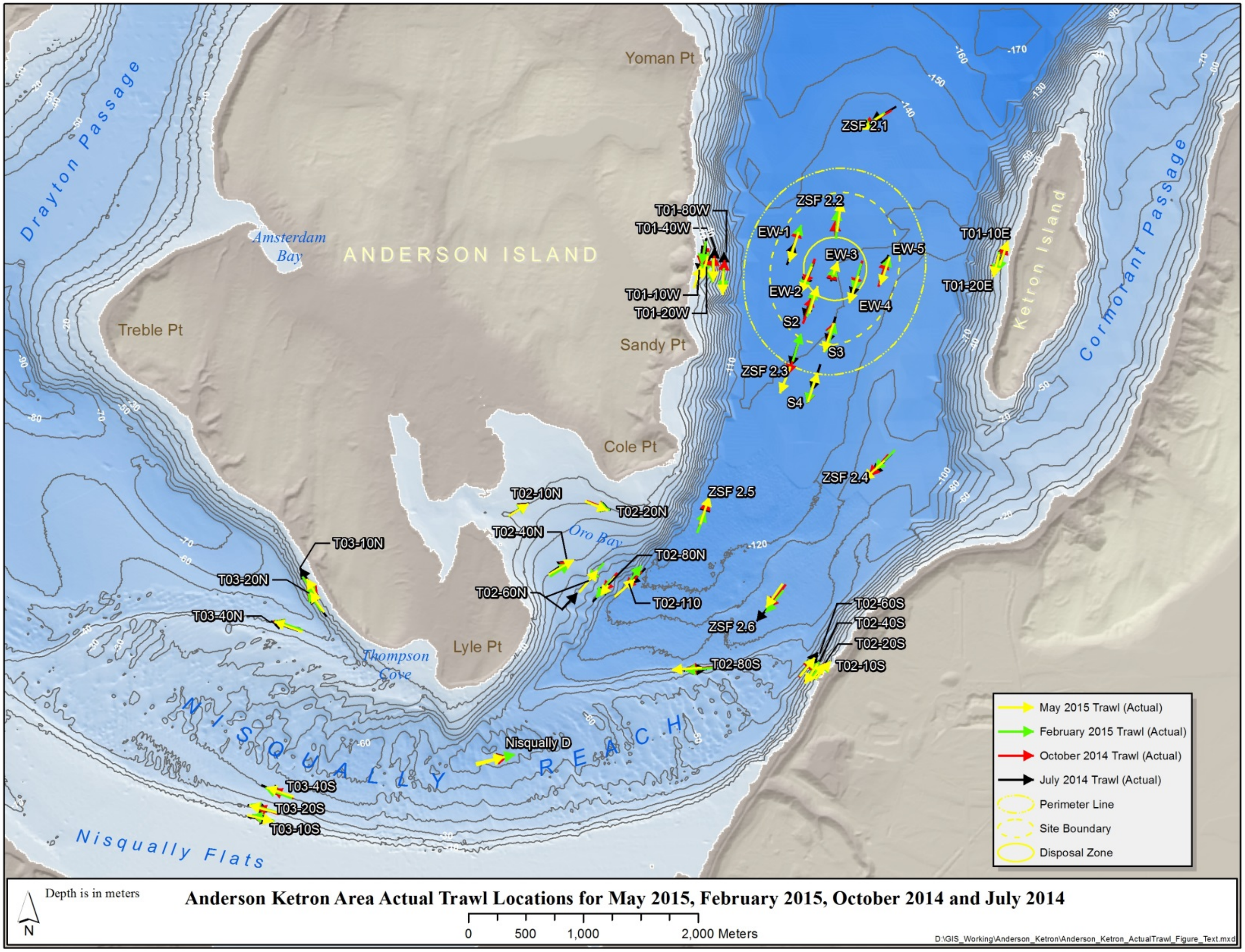


Figure A-1. Beam Trawl Survey Location Overview in the Anderson/Ketron Study Area for the 2014-2015 Survey.

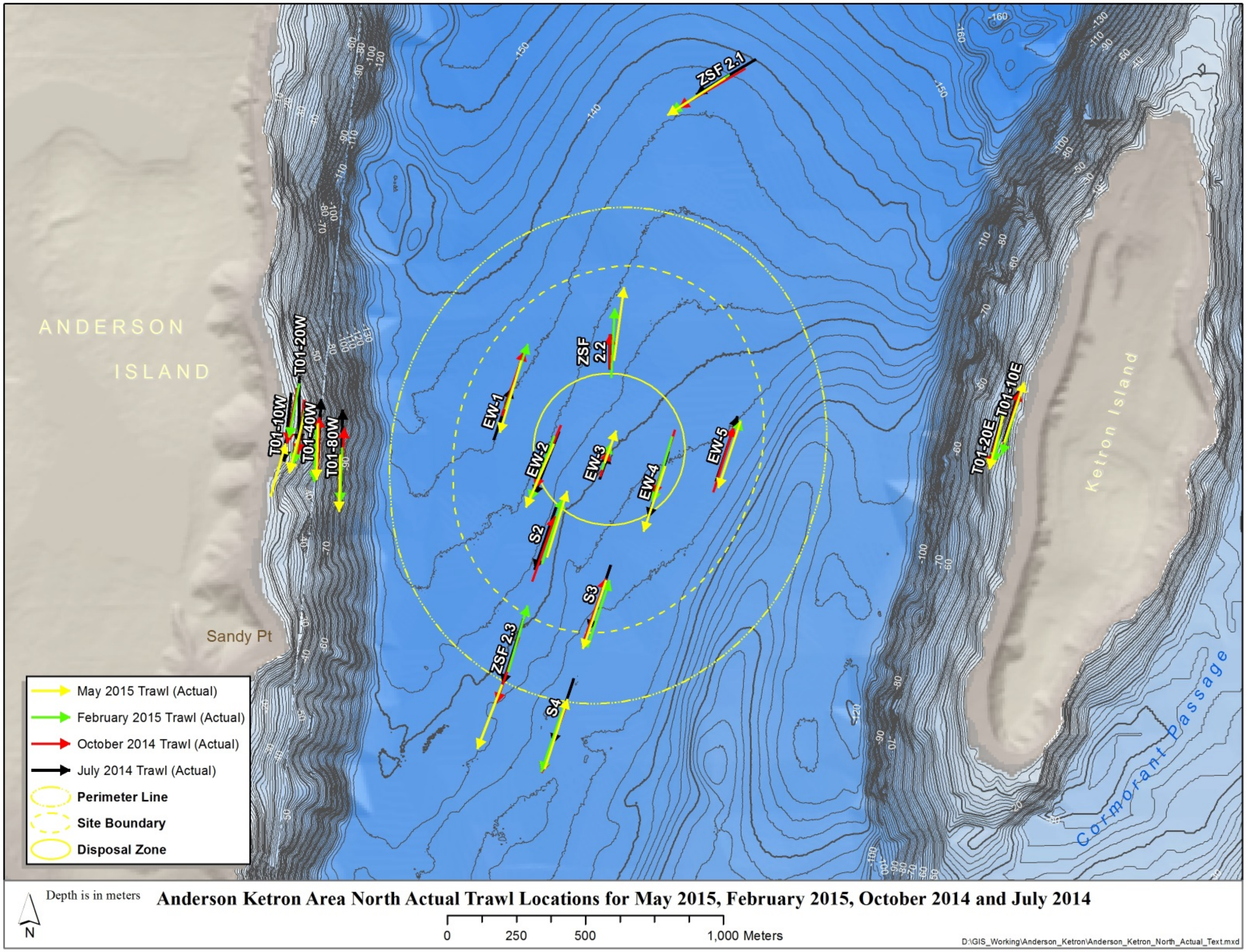


Figure A-2. Beam Trawl Survey Locations in the Anderson/Ketron Disposal Site Area for the 2014-2015 Surveys.

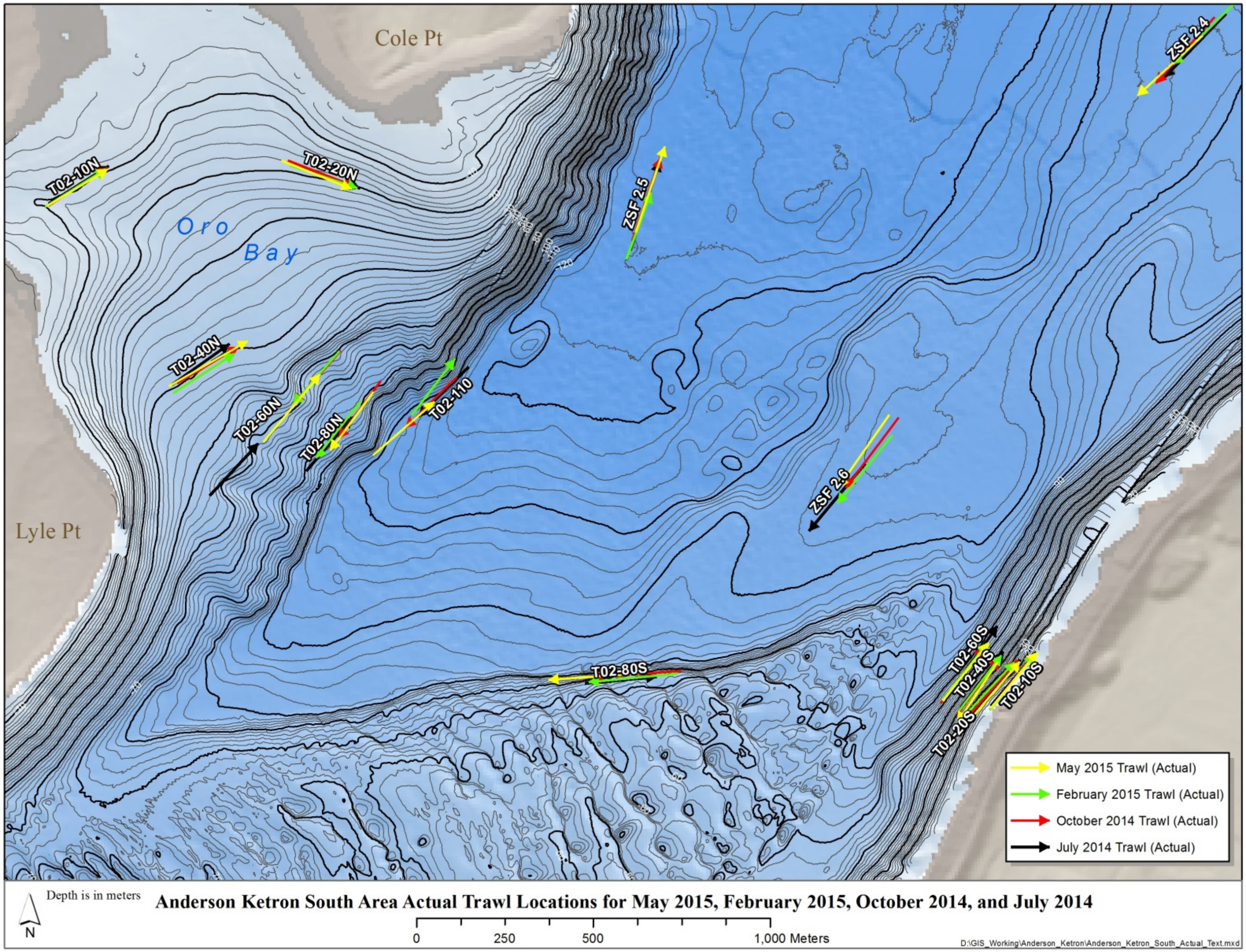


Figure A-3. Beam Trawl Survey Locations in the Anderson/Ketron Southeast Study Area for the 2014-2015 Surveys.

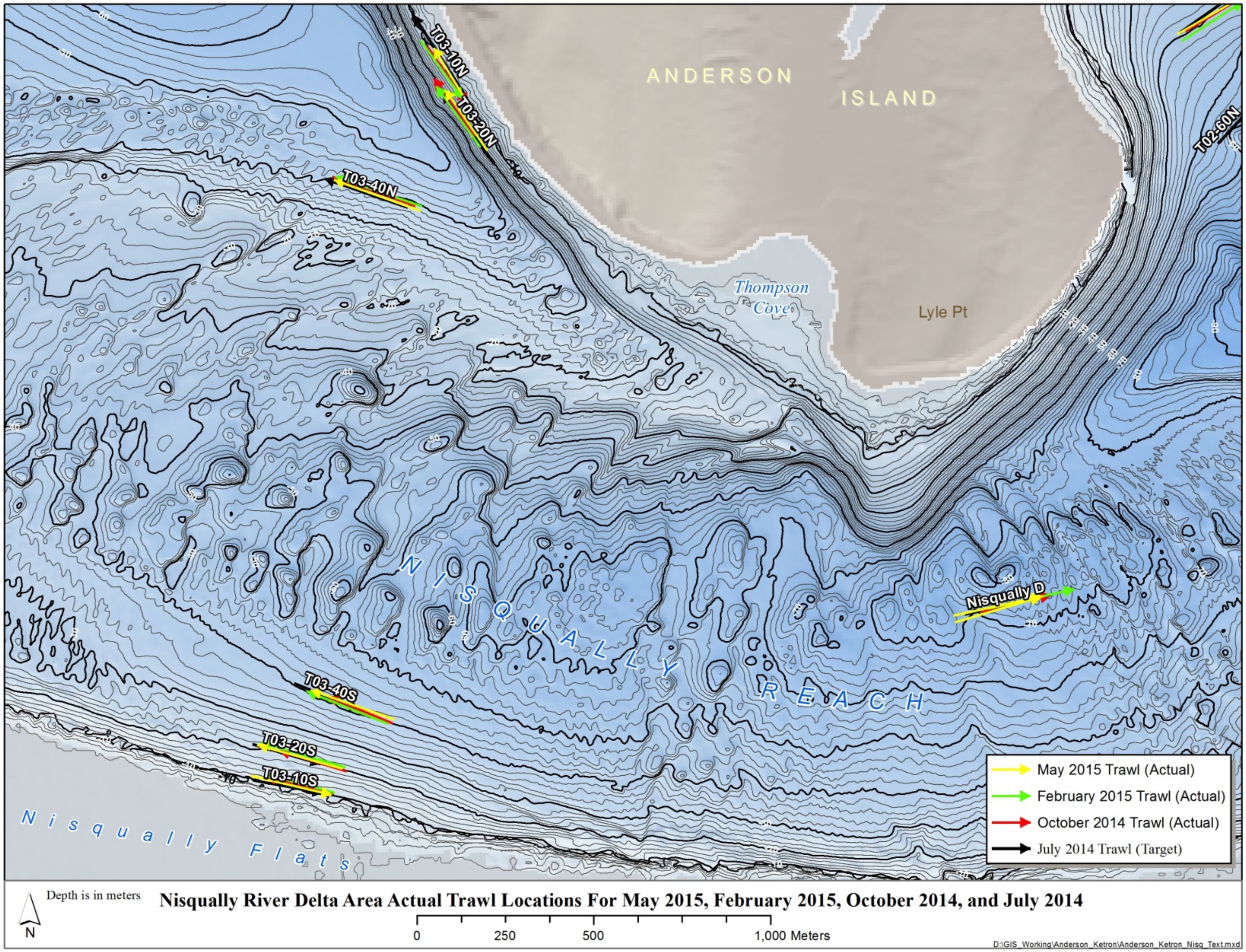


Figure A-4. Beam Trawl Survey Locations in the Nisqually Delta Area for the 2014-2015 Surveys.

Appendix B

1987 and 2014-2015 Anderson/Ketron Study Quarterly Beam Trawl Catch Densities (No./ha) for Selected Invertebrates

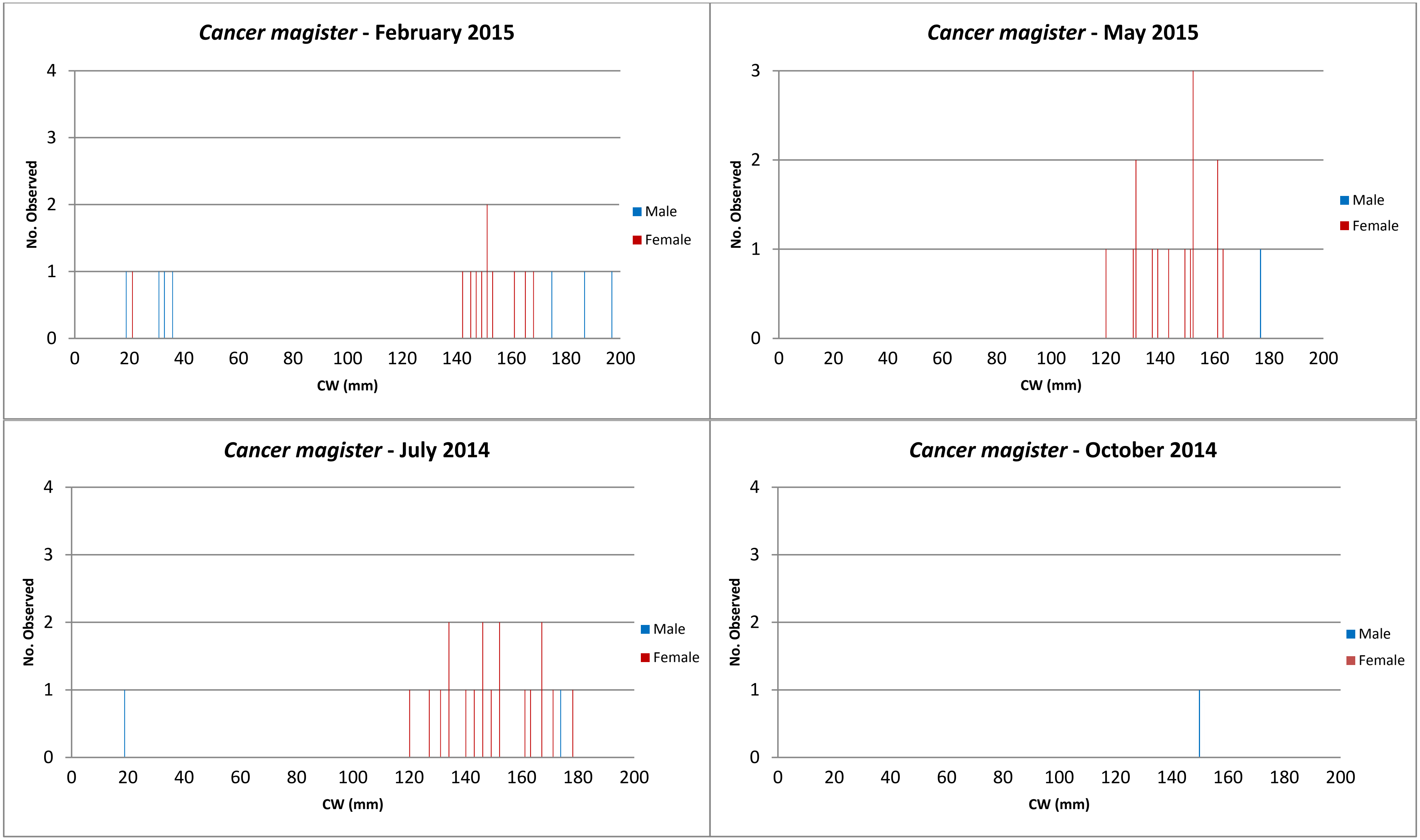
1987 Anderson/Ketron Siting Study Quarterly Beam Trawl Catch Densities (No./ha) for Selected Invertebrates

	Dungeness Crab (*Cancer magister*)				"Rock Crab" (*C. productus + C. gracilis*)				Pandalid Shrimp (all species combined)				Sea Cucumbers (*Parastichopus californicus*)				Sea Stars (all species combined)			
Station	FEB	MAY	JULY	OCT	FEB	MAY	JULY	OCT	FEB	MAY	JULY	OCT	FEB	MAY	JULY	OCT	FEB	MAY	JULY	OCT
ZSF 2.1	0	0	0	0	0	0	19	0	0	0	19	0	37	0	19	0	19	0	56	75
ZSF 2.2	0	0	0	0	19	19	19	75	0	0	0	0	0	19	0	19	0	19	19	0
ZSF 2.3	0	0	0	0	0	0	0	0	0	37	0	0	0	0	0	0	19	19	19	0
ZSF 2.4	0	0	0	0	56	37	0	262	0	75	19	37	0	19	0	37	0	0	19	19
ZSF 2.5	0	0	0	0	0	19	0	75	56	37	19	19	19	0	0	0	0	19	19	0
ZSF 2.6	0	0	0	0	0	19	37	56	0	37	0	0	0	0	0	0	0	19	0	0
T01-10E	0	0	0	0	0	56	94	37	0	19	674	974	187	581	150	356	112	131	375	262
T01-20E	0	0	0	0	19	19	19	131	37	131	281	562	899	449	94	393	225	637	356	506
T01-80W	0	0	0	0	0	75	38	318	94	150	0	19	0	0	0	0	468	637	337	337
T01-40W	0	0	0	0	0	56	19	56	19	0	0	112	75	56	19	112	712	843	1,049	431
T01-20W	0	0	0	0	0	19	112	37	0	0	94	599	112	225	225	225	56	618	393	112
T01-10W	0	0	0	0	56	131	94	243	0	0	131	131	131	131	38	225	37	94	19	56
T02-10S	37	37	0	0	131	94	38	94	0	19	337	0	112	262	337	337	56	75	56	94
T02-20S	37	0	0	0	206	37	131	56	0	19	56	262	506	187	300	225	206	337	150	375
T02-40S	19	0	0	0	19	75	19	19	19	0	0	0	150	19	19	94	318	655	431	581
T02-60S	56	0	19	0	37	19	0	56	19	0	0	19	150	56	187	0	412	300	412	431
T02-80S	19	0	0	19	19	0	0	169	0	19	0	37	637	1,142	787	1,816	37	19	19	56
T02-110	0	0	0	0	0	0	19	75	0	37	169	0	112	281	56	94	75	56	56	19
T02-80N	0	0	0	0	19	37	19	131	0	0	0	19	0	0	0	0	131	206	150	206
T02-60N	0	0	0	0	19	56	56	131	56	0	19	169	0	0	19	0	318	75	94	112
T02-40N	19	0	0	0	56	0	56	75	0	0	0	0	0	0	0	19	112	94	56	37
T02-20N	37	0	0	0	356	37	94	112	0	0	0	19	19	37	0	0	318	225	262	131
T02-10N	0	0	0	0	37	112	206	56	0	0	19	2,154	168	56	56	0	262	431	56	0
T03-10S	37	19	56	0	37	56	38	487	0	0	19	0	0	0	0	0	0	0	0	0
T03-20S	0	0	0	0	131	19	0	0	19	75	0	318	0	19	0	0	0	0	0	0
T03-40S	0	0	0	0	0	19	38	19	0	0	0	243	0	19	0	37	0	19	0	150
T03-40N	0	0	0	0	0	37	19	19	0	19	0	880	0	243	75	449	0	599	393	768
T03-20N	0	0	0	0	19	0	0	94	0	0	0	0	1,086	637	431	1,011	187	356	169	487
T03-10N	0	37	0	0	37	19	0	19	0	0	131	749	712	899	918	449	94	56	112	300
Nisqually D	0	0	0	0	0	0	19	0	19	0	0	0	0	0	0	0	0	0	0	0
Mean Density (original 30 stations)	**8.7**	**3.1**	**2.5**	**0.6**	**42.4**	**35.6**	**40.1**	**96.7**	**11.3**	**22.5**	**66.2**	**244.1**	**170.4**	**177.9**	**124.3**	**196.6**	**139.1**	**218.0**	**169.2**	**184.8**

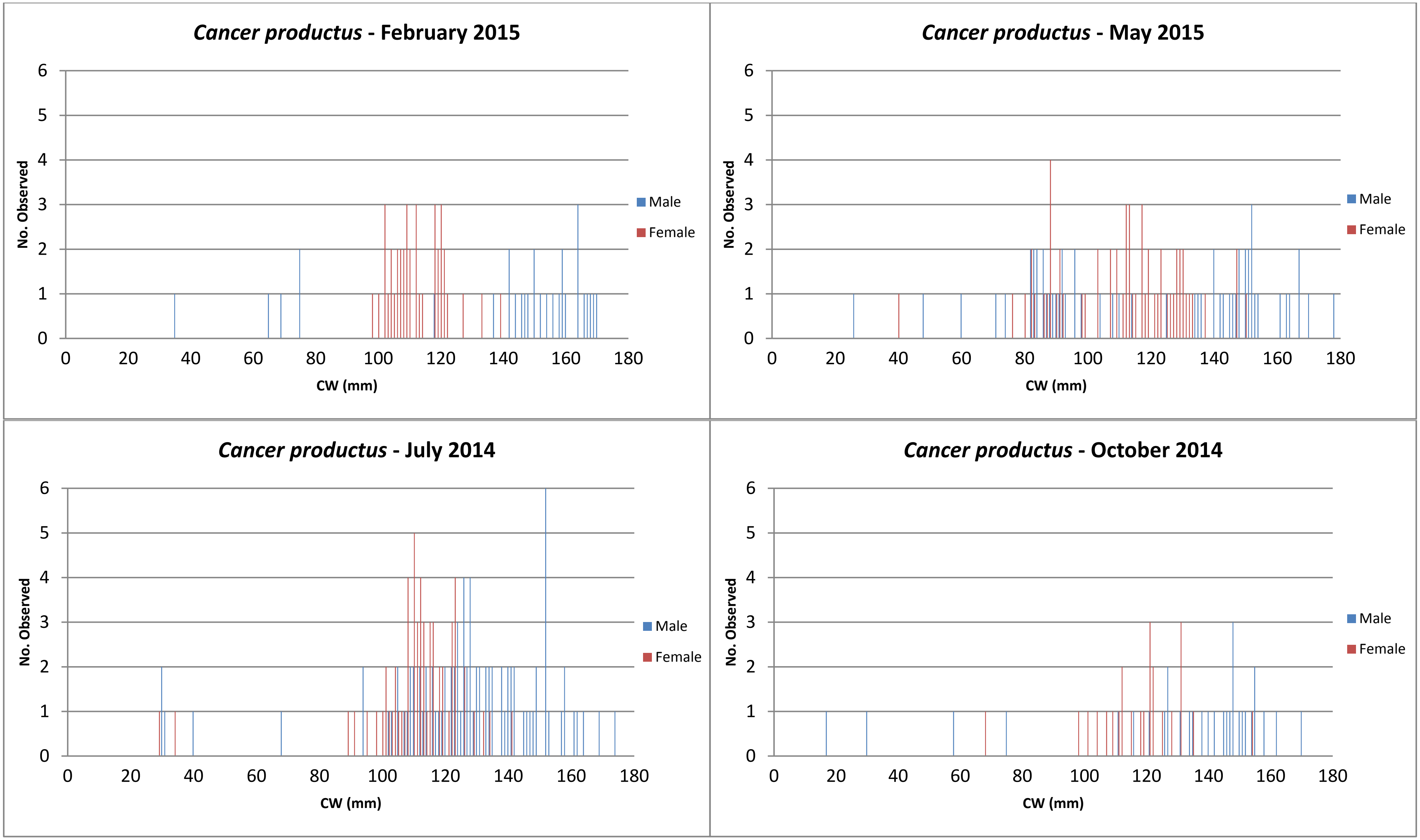
2014-2015 Anderson/Ketron Study Quarterly Beam Trawl Catch Densities (No./ha) for Selected Invertebrates

	Dungeness Crab (*Cancer magister*)				"Rock Crab" (*C. productus + C. gracilis*)				Pandalid Shrimp (all species combined)				California Sea Cucumber (*Parastichopus californicus*)				Sea Stars (all species combined)			
Station	FEB	MAY	JULY	OCT	FEB	MAY	JULY	OCT	FEB	MAY	JULY	OCT	FEB	MAY	JULY	OCT	FEB	MAY	JULY	OCT
ZSF 2.1	0	17	34	0	35	157	35	226	433	2,157	2,122	1,200	52	35	0	35	35	17	0	17
ZSF 2.2	0	0	0	0	35	0	103	0	52	2,101	2,191	205	0	0	34	0	17	32	34	0
ZSF 2.3	0	0	0	0	17	69	0	0	433	2,252	995	416	0	0	0	0	0	0	0	0
ZSF 2.4	0	0	16	0	70	156	487	87	157	1,542	8,104	296	0	0	0	0	0	17	0	0
ZSF 2.5	0	0	17	0	779	1,184	490	557	433	2,318	7,388	3,183	43	0	0	0	22	34	49	17
ZSF 2.6	0	35	35	0	384	831	489	576	2,689	2,442	10,372	5,622	0	0	0	0	17	35	87	17
T01-10E	0	0	0	0	107	284	216	343	0	0	0	321	64	0	43	0	256	170	238	64
T01-20E	0	0	0	0	195	84	43	184	130	84	261	959	389	739	196	306	216	253	348	204
T01-80W	0	0	16	0	387	2,467	3,466	2,261	10,697	6,564	32,719	5,109	0	21	47	87	129	167	238	261
T01-40W	0	0	0	0	1,684	1,245	713	1,000	1,449	3,651	1,670	9,630	341	106	243	174	128	274	296	370
T01-20W	0	0	0	0	192	437	419	240	85	166	1,152	5,921	149	187	70	175	362	416	349	524
T01-10W	0	22	0	0	239	303	678	257	0	22	696	4,819	130	0	0	236	478	87	243	407
T02-10S	0	0	0	0	65	210	174	153	344	1,869	16,500	12,869	108	273	196	153	796	1,071	1,804	109
T02-20S	0	0	0	0	87	761	303	258	1,666	2,174	40,580	51,679	735	1,304	281	624	238	826	2,726	108
T02-40S	0	0	0	0	324	84	283	350	22,907	25,897	41,848	67,096	173	148	87	284	108	169	5,130	22
T02-60S	21	0	22	22	341	248	2,282	281	15,153	18,033	26,065	40,645	64	21	43	173	149	828	2,734	43
T02-80S	52	115	234	0	863	494	980	278	2,553	3,030	2,643	2,017	0	0	0	17	17	0	43	0
T02-110	0	0	0	0	433	245	1,848	792	3,483	4,254	11,609	1,007	0	0	0	0	0	19	109	64
T02-80N	0	42	0	0	685	338	1,130	584	23,902	4,411	5,326	6,792	0	0	0	0	0	42	0	22
T02-60N	87	0	0	0	457	87	714	454	3,022	1,739	216	4,067	0	87	22	0	43	243	303	1,211
T02-40N	0	0	0	0	357	102	261	215	42	0	0	0	0	0	0	0	168	85	22	0
T02-20N	0	20	21	0	130	607	1,221	476	22	0	86	65	0	0	21	0	43	40	64	0
T02-10N	0	0	0	0	65	624	973	393	22	0	1,341	3,496	0	0	0	0	195	258	108	22
T03-10S	43	0	0	0	280	352	1,217	935	0	0	196	0	0	0	22	0	0	19	0	0
T03-20S	17	0	22	0	157	70	324	634	0	139	1,038	459	0	0	0	0	0	0	43	0
T03-40S	35	0	22	0	87	17	196	481	0	0	0	0	0	0	22	0	0	0	0	0
T03-40N	17	0	17	0	252	83	122	139	0	0	0	87	0	0	0	0	0	0	0	0
T03-20N	102	0	0	0	82	166	383	587	20	0	0	109	184	166	261	391	429	435	504	957
T03-10N	0	21	0	0	129	84	124	326	0	0	15	348	409	42	217	239	538	732	712	304
Nisqually D	0	0	0	0	226	0	0	150	365	0	35	64	0	0	0	0	0	0	0	0
Mean Density (original 30 stations)	**12.5**	**9.1**	**15.2**	**0.7**	**304.7**	**392.9**	**655.8**	**440.6**	**3,002.0**	**2,828.2**	**7,172.3**	**7,616.0**	**94.7**	**104.2**	**60.2**	**96.5**	**146.2**	**209.0**	**539.5**	**158.1**
EW-1*	0	0	0	0	17	0	65	17	121	555	1,283	313	0	0	0	0	0	0	0	17
EW-2*	0	0	0	0	87	52	0	263	35	2,217	502	245	0	0	0	0	0	0	0	0
EW-3*	0	0	0	0	1,205	1,691	344	391	258	1,898	5,424	304	0	0	0	0	0	173	43	87
EW-4*	0	0	17	0	52	52	35	122	52	1,001	3,257	435	0	0	0	0	0	0	0	0
EW-5*	0	0	0	0	35	34	0	0	104	85	1,757	210	0	0	0	0	0	0	0	0
S-2*	0	17	0	0	35	86	35	17	174	1,104	528	157	0	0	0	0	0	0	0	0
S-3*	0	0	0	0	68	33	0	51	135	1,861	821	171	0	0	0	0	0	16	0	0
S-4*	0	0	0	0	33	81	17	35	0	1,022	470	191	0	0	0	0	50	0	0	0
Mean Density (all 38 stations)	**9.8**	**7.6**	**12.5**	**0.6**	**280.8**	**363.6**	**530.8**	**371.4**	**2,393.2**	**2,489.2**	**6,031.8**	**6,065.9**	**74.8**	**82.3**	**47.5**	**76.2**	**116.7**	**169.9**	**427.0**	**127.6**

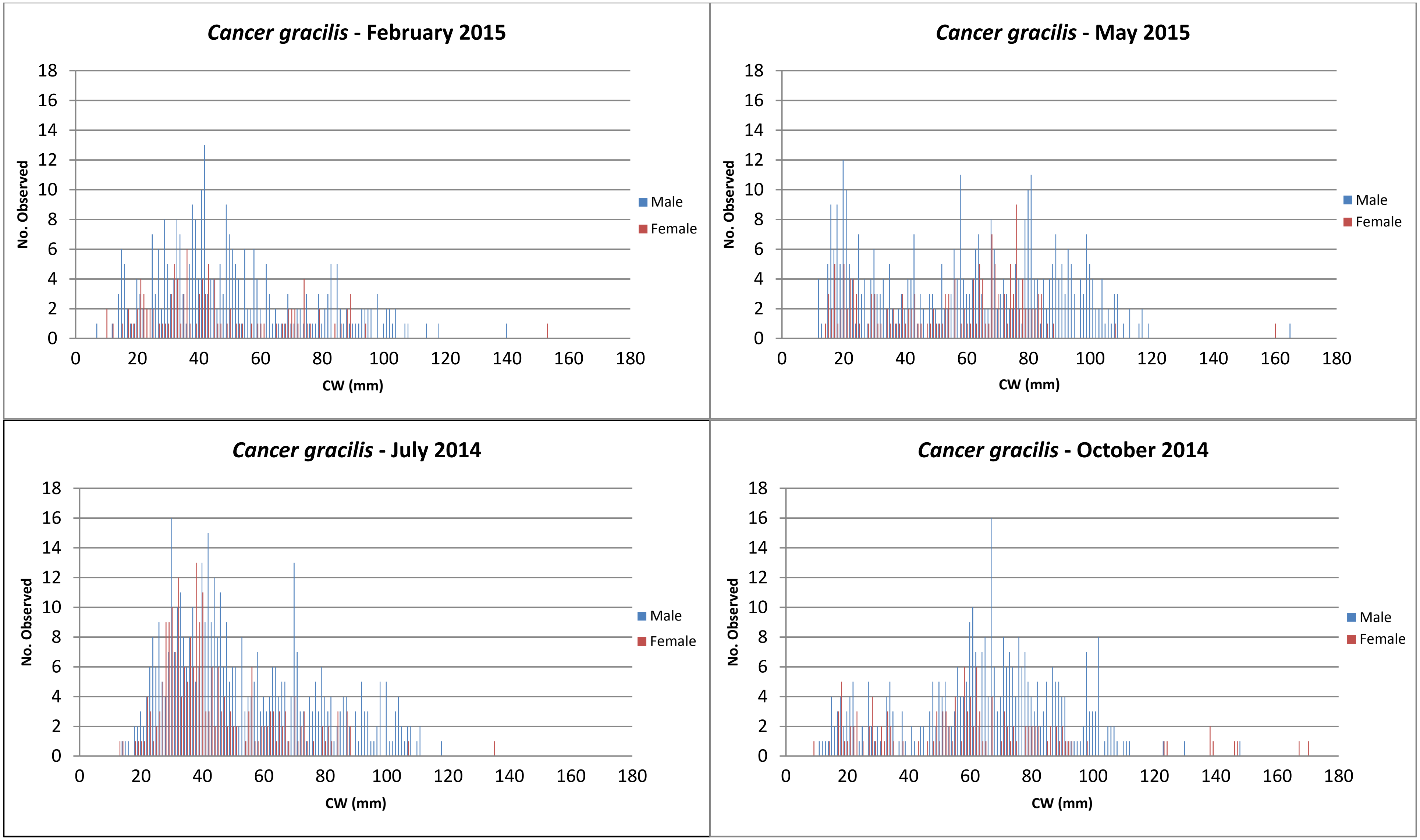
Appendix C
Size Frequency Distributions of Crabs of Potential Fisheries Importance Captured During the 2014-2015 Anderson/Ketron Study



2014-2015 Quarterly Size Frequency Distributions of the Dungeness Crab (*Cancer magister*).

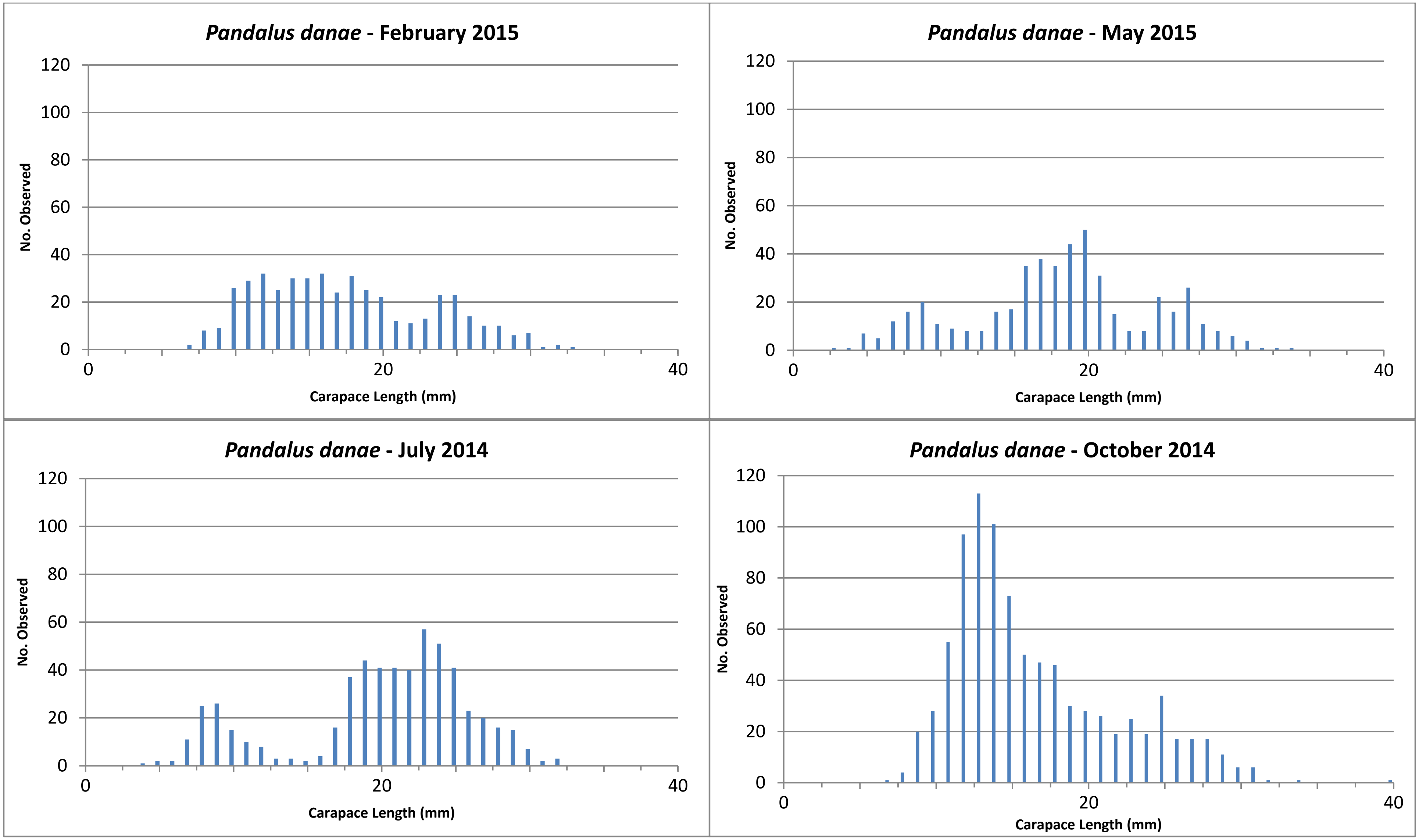


2014-2015 Quarterly Size Frequency Distributions of the Red Rock Crab (*Cancer productus*).

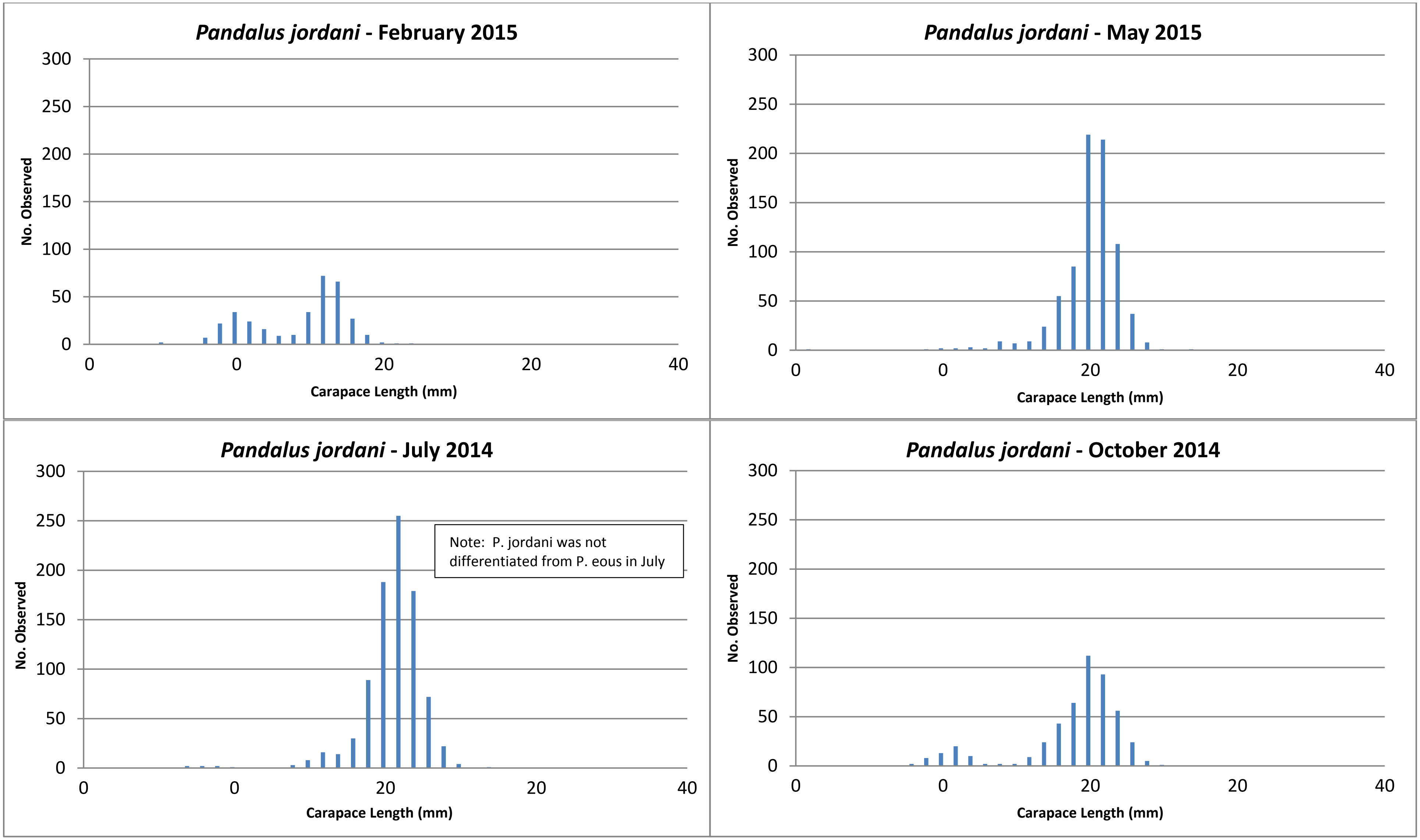


2014-2015 Quarterly Size Frequency Distributions of the Graceful *Cancer* Crab (*Cancer gracilis*).

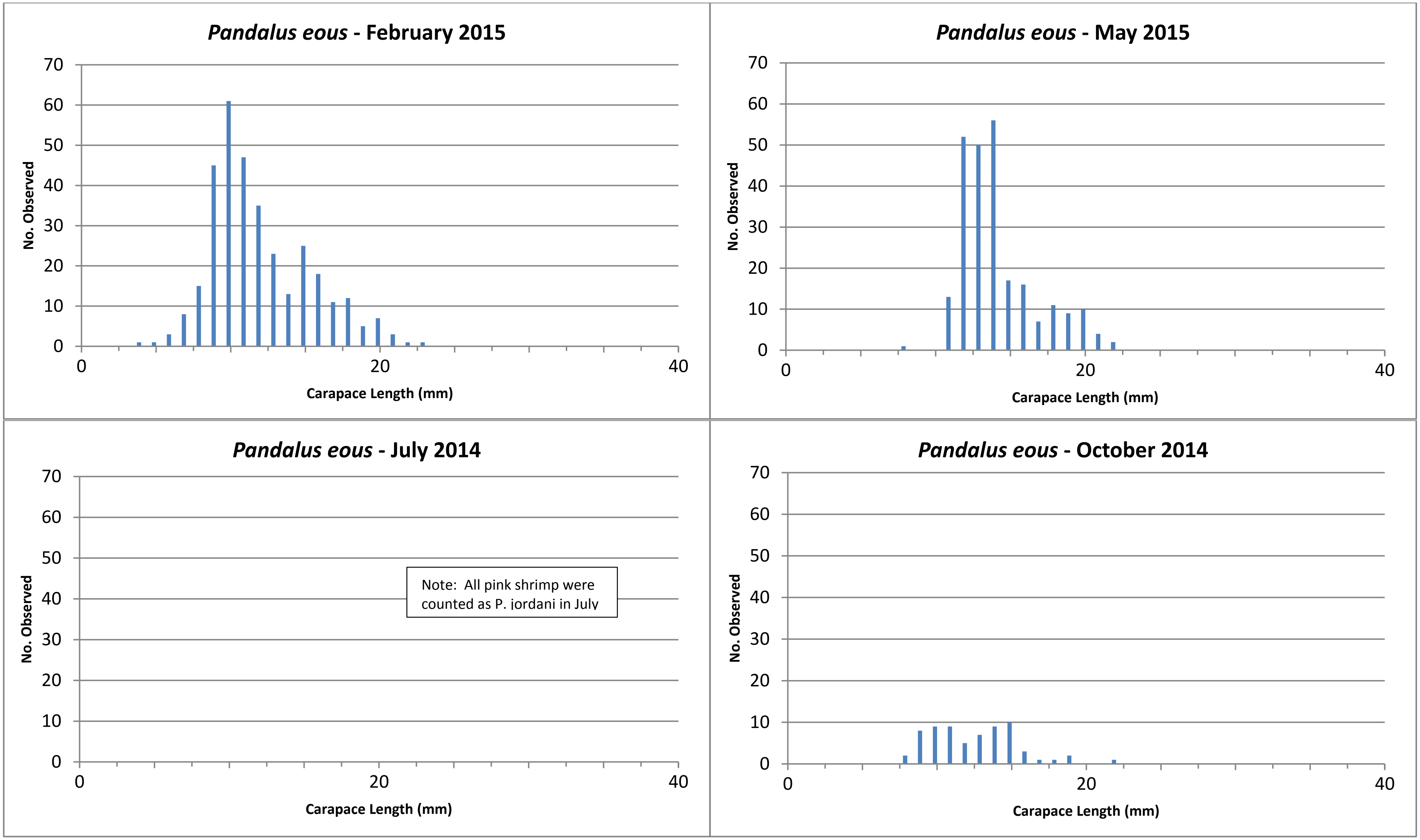
Appendix D
Size Frequency Distributions of Pandalid Shrimp Captured During the 2014-2015 Anderson/Ketron Study



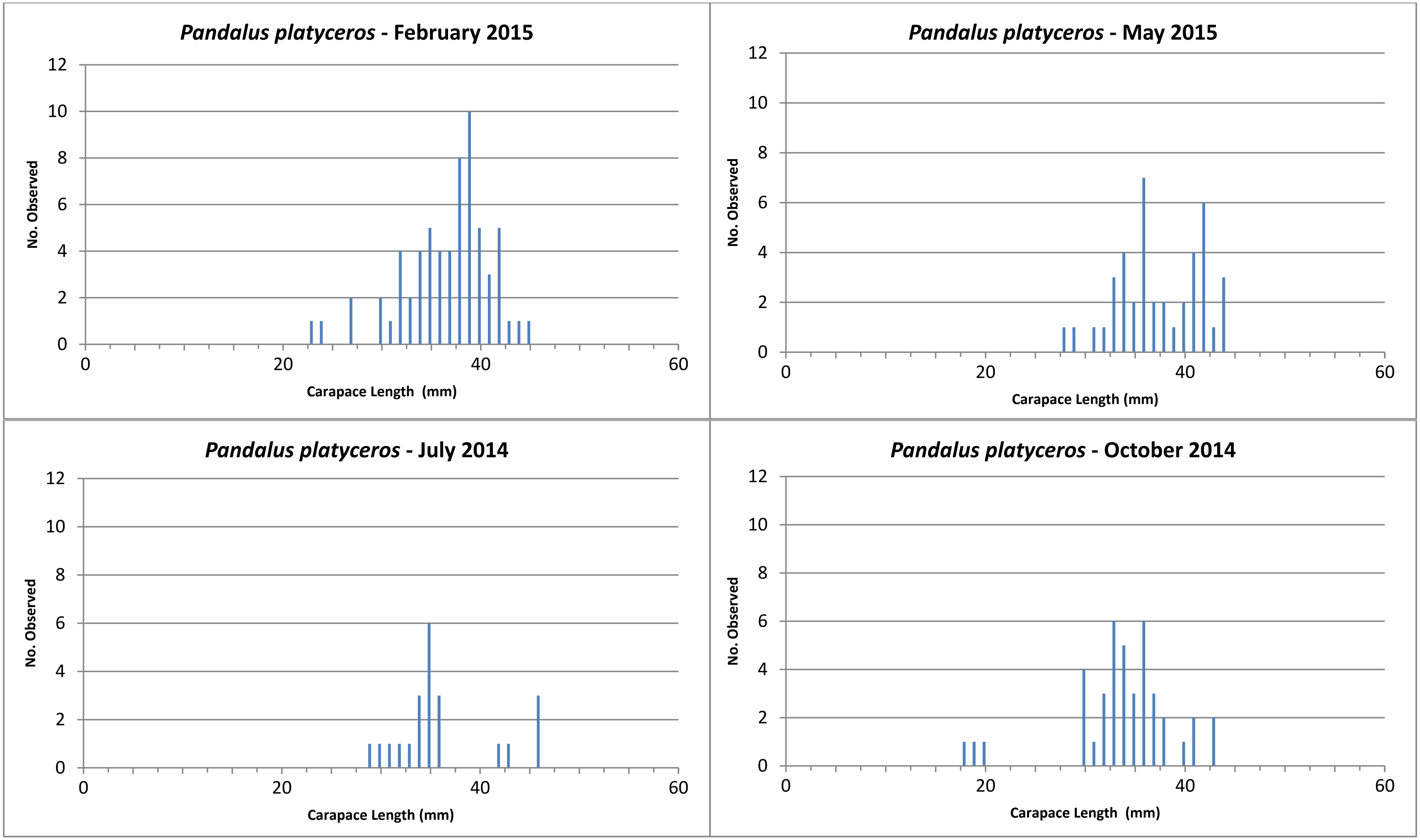
2014-2015 Quarterly Size Frequency Distributions of the Dock Shrimp (*Pandalus danae*).



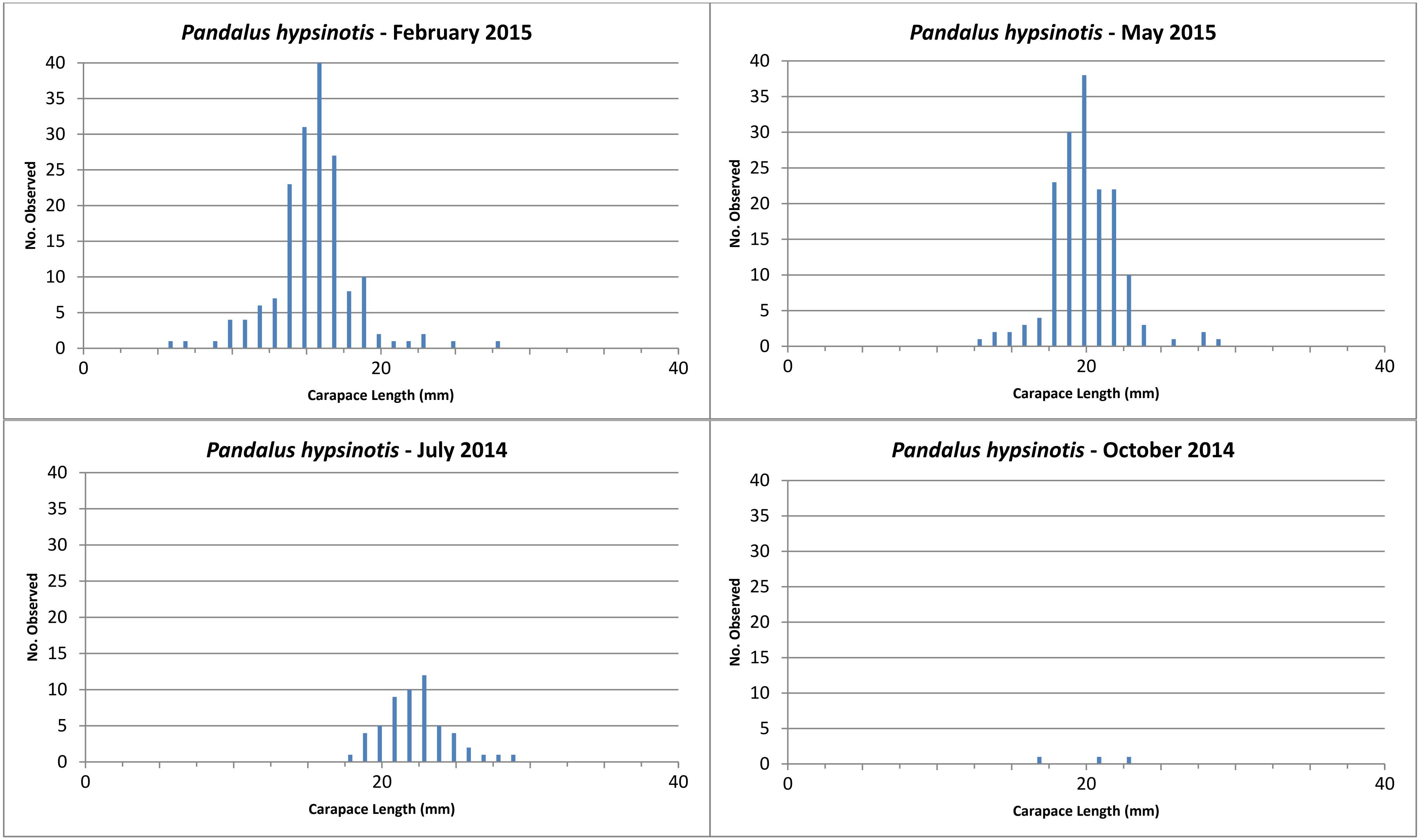
2014-2015 Quarterly Size Frequency Distributions of the Smooth Pink Shrimp (*Pandalus jordani*).



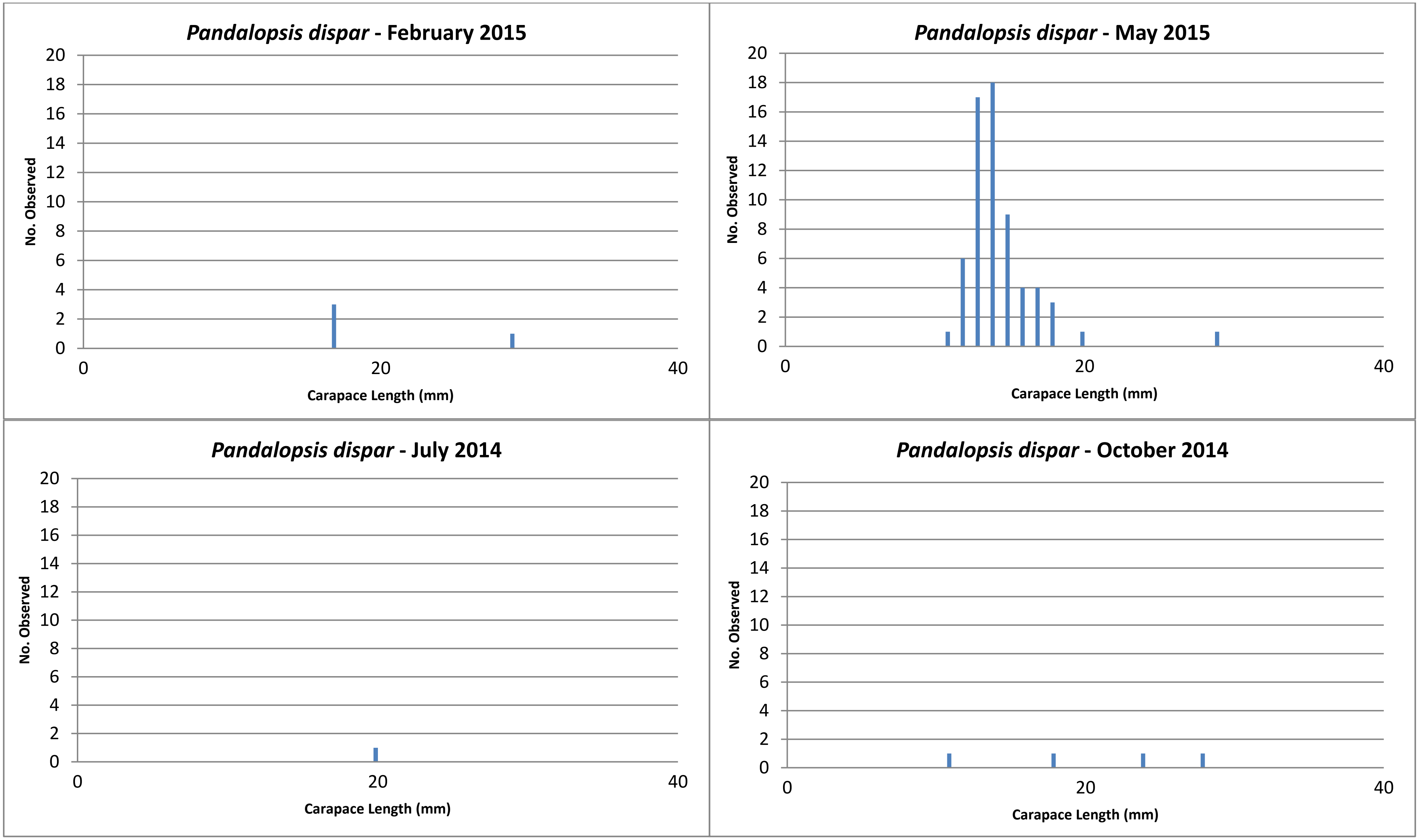
2014-2015 Quarterly Size Frequency Distributions of the Alaskan Pink Shrimp (*Pandalus eous*).



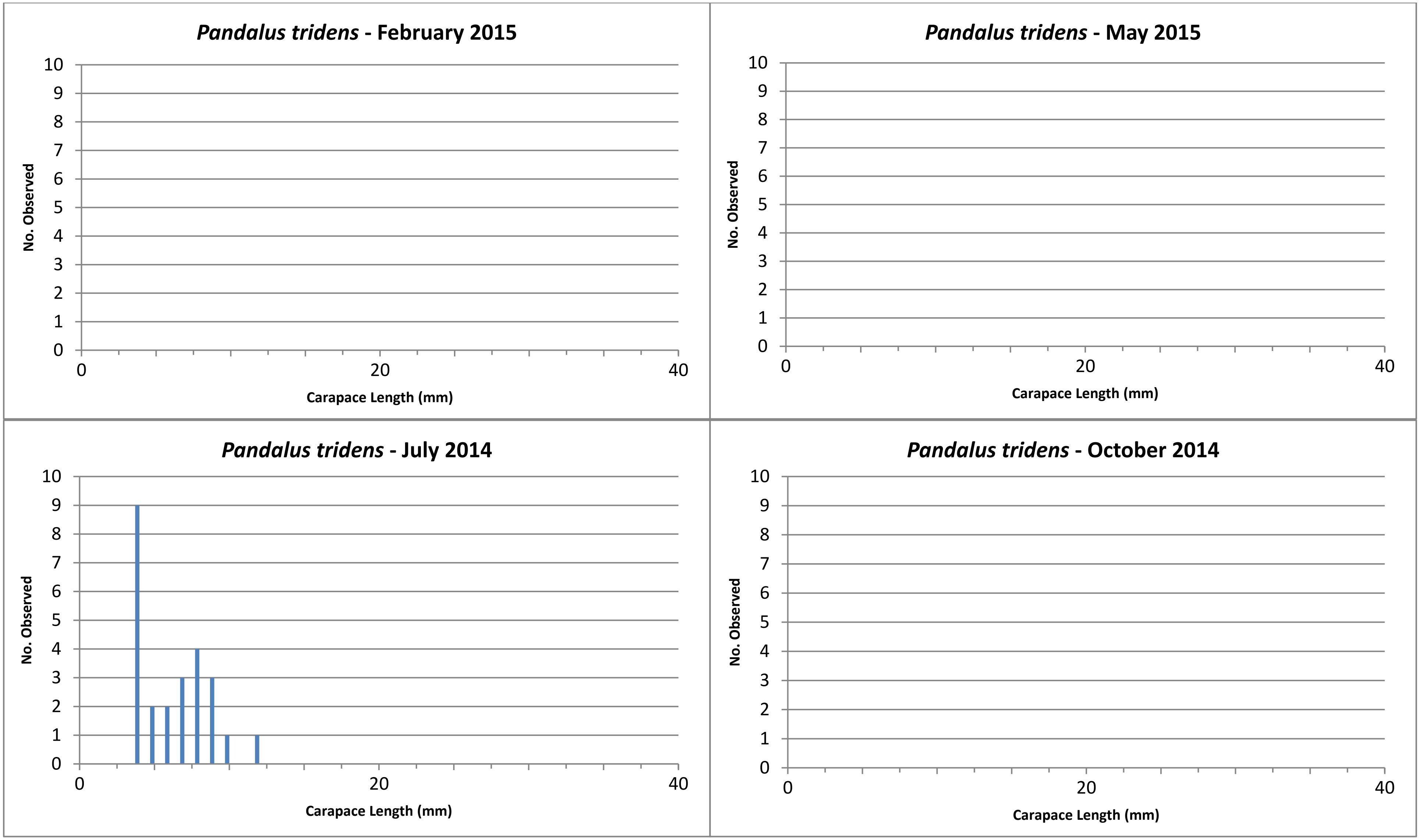
2014-2015 Quarterly Size Frequency Distributions of the Spot Prawn (*Pandalus platyceros*).



2014-2015 Quarterly Size Frequency Distributions of the Coonstripe Shrimp (*Pandalus hypsinotus*).



2014-2015 Quarterly Size Frequency Distributions of the Sidestripe Shrimp (*Pandalopsis dispar*).



2014-2015 Quarterly Size Frequency Distributions of the Yellowleg Pandalid (*Pandalus tridens*).

Appendix E
2014-2015 Anderson/Ketron Study Quarterly Beam Trawl Catch Totals for Other Invertebrates

Other Invertebrates

Species	Common Name	Total Quarterly Catch Totals			
		February	May	July	October
Acanthodoris brunnea	Brown spiny doris	15	8	---	---
Aeolidia papillosa	Shag-rug aeolis	1	---	---	1
Anemone sp.	Anemone sp.	1	---	---	1
Armina californica	Striped nudibranch	143	119	93	114
Brittle star sp.	Brittle star	---	---	36	---
Cancer oregonensis	Pygmy rock crab	6	15	1	20
Ceramaster sp.	Sea star	---	---	1	---
Chorilia longipes	Longhorn decorator crab	2	1	---	---
Crangon sp.	Crangon shrimp	781	1,330	1,698	777
Crossaster papposus	Common sunstar	7	7	19	10
Cucumaria miniata	Orange sea cucumber	---	---	---	2
Cucumaria piperata	Cucumaria sea cucumber	---	1	1	---
Dendronotus diversicolor	Multicolor frond-aeolis	---	1	---	---
Dendronotus iris	Giant frond-aeolis	10	112	---	---
Dendronotus rufus	Red frond-aeolis	---	1	3	---
Dendronotus subramosus	Stubby frond-aeolis	5	---	---	---
Dendronotus sp.	Nudibranch	18	44	51	68
Dermasterias imbricata	Leather sea star	11	9	4	6
Dirona albolineata	White lined Dirona nudibranch	4	4	---	43
Dirona sp.	Nudibranch	---	---	---	75
Discodoris sandiegensis	Leopard dorid, nudibranch	---	---	1	---
Eualus sp.	Eualid shrimp	36	---	---	16
Eualus subtilis	Eualid shrimp	---	2	---	---
Eualus suckleyi	Shortscale eualid shrimp	151	107	225	720
Eualus townsendi	Townsend's eualid	4	5	1	38
Eupentacta quinquesemita	White sea cucumber	2	---	---	3
Evasterias troschelii	Mottled sea star	107	202	615	48
Flabellina verrucosa	Red-finger aeolis	1	---	---	---
Hemigrapsus oregonensis	Yellow shore crab	1	3	---	3
Heptacarpus brevirostris	Shortspine shrimp, Stout coastal shrimp	4	---	---	---
Heptacarpus sitchensis	Sitka shrimp	4	---	2	1
Heptacarpus sp.	Heptacarpid coastal shrimp	17	51	---	---
Heptacarpus stimpsoni	Stimpson coastal shrimp	---	32	---	---
Heptacarpus stylus	Stiletto coastal shrimp	7	1	---	2
Heptacarpus tenuissimus	Slender coastal shrimp	152	142	1	43
Heptacarpus tridens	Threespine coastal shrimp	6	4	97	---
Hermissenda crassicornis (Phidiana crassicornis)	Nudibranch	---	2	---	4
Hippolytidae	Unidentified small shrimp	---	124	---	---
Hyas lyratus	Pacific lyre crab	---	---	2	4
Lebbeus groenlandicus	Spiny lebbeid	3	---	158	17
Lophopanopeus bellus	Black-clawed crab	34	53	31	76
Luidia foliolata	Sand star	8	6	6	3
Masterius sp.	Sea star	---	---	2	---
Mediaster sp.	Sea star	1	---	---	---
Metacrangon munita	Coastal spinyhead shrimp	---	67	---	50
Metridium	Sea anemone	440	600	---	---
Munida quadrispina	Squat lobster	42	16	50	43
Neotrypaea californiensis	Bay ghost shrimp	---	---	1	---
Nudibranch juvenile	nudibranch	---	3	---	---
Octopus leioderma	Smoothskin octopus	---	1	---	---
Octopus rubescens	East Pacific red octopus	2	1	5	2
Ophiuridae	Brittle star	12	18	---	91
Oregonia gracilis	Graceful decorator crab	529	514	513	866
Pagurid sp.	Hermit crab	149	146	134	194
Pandalopsis dispar	Sidestriped shrimp	---	---	---	2
Pandalus goniurus	Humpy shrimp	---	---	23	---
Paracrangon echinata	Horned shrimp	97	91	96	91
Parastichopus californicus	California Sea Cucumber	133	148	94	135
Pentaca sp.	Sea cucumber sp.	---	---	2	---
Pentamera populifera	White sea cucumber	17	38	6	26
Petrolisthes cabrillo	Cabrillo porcelain crab	1	---	---	---
Petrolisthes eriomerus	Flattop crab	---	3	---	---
Petrolisthes rathbunae	Rathbun procelain crab	1	---	---	---
Pinnotheridae	Pea crab	1	3		8
Pisaster brevaspinus	Short-spined sea star	14	19	16	4
Pisaster ochraceus	Ochre sea star	2	---	---	---
Pisaster sp.	Sea star	---	---	---	1
Porcellanidae	Porcelain crab	5	3	---	2
Pteraser tesselatus	Slime star	---	---	1	---
Pugettia dalli	Spined kelp crab	---	---	---	1
Pugettia gracilis	Graceful kelp crab	---	3	24	8
Pugettia producta	Northern kelp crab	2	11	29	14

Other Invertebrates continued

Species	Common Name	February	May	July	October
Pugettia richii	Cryptic kelp crab	5	3	2	7
Pugettia sp.	Kelp crab sp.	---	---	6	4
Pycnopodia helianthoides	Sunflower sea star	34	37	44	34
Rossia pacifica	North Pacific bobtail squid	1	1	---	---
Sclerocrangon sp.	Bering shrimp	28	---	---	---
Scyra acutifrons	Sharpnose crab	63	52	20	90
Sea star sp.	Unidentified sea star	1	---	1	---
Solaster dawsonii	Morning Sun Star	1	---	5	4
Solaster dulcini	Sea star	---	---	1	---
Solaster sp.	Sea star	1	---	2	1
Solaster simpsondae	Sea star	---	---	1	---
Solaster stimpsonii	Stimpson's sun star	10	12	28	21
Spirontocaris holmesi	Slender blade shrimp	280	217	---	---
Spirontocaris lamellicornis	Dana's bladed shrimp	61	77	---	255
Spirontocaris prionota	Deep blade shrimp	9	7	---	6
Spirontocaris sp.	Blade shrimp	---	---	2	---
Strongylocentrotus droebachiensis	Green sea urchin	4	8	10	22
Telmessus cheiragonus	Helmet crab	---	2	---	---
Triophiacarpenteri sp.	Nudibranch	---	---	1	---
Tritonia diomedea	Rosy tritonia	20	99	---	---
Tritonia festiva	Triton's nudibranch	3	16	15	34
Tritonia sp.	Nudibranch	12	---	---	---
Unidentified juvenile shrimp	Juvenile shrimp	---	10	28	541
Unknown Hippolytidae shrimp	Unknown Hippolytidae shrimp	32	10	---	---
unknown nudibranch sp.	Nudibranch	---	---	---	1
Unknown white sea cucumber	Unknown white sea cucumber	1	10	---	---
Upogebia pugettensis	Blue mud shrimp	1	10	---	2

Appendix F
2014-2015 Anderson/Ketron Study Quarterly Beam Trawl Catch Densities (No./ha) for Fish

February 2015 Fish Density

Species	EW-1	EW-2	EW-3	EW-4	EW-5	Nisqually D	S-2	S-3	S-4	T01-10E	T01-10W	T01-20E	T01-20W	T01-40W	T01-80W	T02-10N	T02-10S	T02-110	T02-20N	T02-20S	T02-40N	T02-40S
Arrowtooth flounder																						
Bay goby																						
Bay pipefish													277			43	22		65	22		
Big skate												22										
Blackbelly eelpout	537	589	861	646	779	17	1252	795	498					2217	108			952			378	22
Blacktip poacher															194			108				
Brown rockfish		17													22							
Buffalo sculpin				17		70				43		65	21	64	172		474			627		
Butter sole						661																
California headlightfish							17															
C-O sole											109	22	21	21	22		22					
Copper rockfish														21								
Crescent gunnel															22					22		108
Dover sole																						
English sole	17		43	17	17		35	17	50					64	22	43		43	22		42	
Flathead sole								17														
Great sculpin																				22		
Grunt sculpin												43		21								65
Longnose skate																						
Longspine combfish																						
Northern spearnose poacher														21						22		
Pacific hake					35																	
Pacific sanddab		17		17														22				
Pacific spiny lumpsucker														21								
Pacific staghorn sculpin	52	35	215	35		17								43	65		43	65				22
Pacific tomcod			43		17		17	34	17									22				
Padded sculpin										21	22	22		384	215		22			411		865
Painted greenling										21												
Penpoint gunnel																						
Plainfin midshipman	243	173	1378	175	139	35	313	491	199			43		1236	538			324	22		147	43
Pygmy poacher								17			22	216	64	448					108	151	210	411
Red brotula				35																		
Rex sole	17																	43				
Rock sole						17				43		87	21									
Roughback sculpin			86			35			33	192	304	411	512	1300	1507	108	86	476	195	87	252	909
Saddleback gunnel														21	22		86			260	21	
Sailfin sculpin														128								151
Sand sole										21												
Shiner perch				17	121	17	17	51														
Slender sole	17	35	43		35		52	51	83									22				
Slim sculpin						17								21							21	
Snailfish																			22		21	
Snake prickleback					17																	
Speckled sanddab						35				277	65	324	277	3538	215	87	22		281	108	609	714
Spinyhead sculpin															22							
Starry flounder																						
Sturgeon poacher						70								43								108

February 2015 Fish Density continued

Species	T02-60N	T02-60S	T02-80N	T02-80S	T03-10N	T03-10S	T03-20N	T03-20S	T03-40N	T03-40S	ZSF 2.1	ZSF 2.2	ZSF 2.3	ZSF 2.4	ZSF 2.5	ZSF 2.6
Arrowtooth flounder	22															
Bay goby														17		
Bay pipefish								278		17						
Big skate					22											
Blackbelly eelpout	1696		792	466							1265	759	1299	1205	1709	1449
Blacktip poacher	326		300											17		402
Brown rockfish	22															
Buffalo sculpin		213		35	43	43	61	783		35						
Butter sole				345		1421	20	157	400	733						175
California headlightfish																
C-O sole					65	22	61	70		17					65	17
Copper rockfish																
Crescent gunnel																
Dover sole															22	
English sole			43							17	17	17	17	157		17
Flathead sole											52	17	17	17		
Great sculpin															151	
Grunt sculpin																
Longnose skate															43	
Longspine combfish															22	
Northern spearnose poacher																
Pacific hake																
Pacific sanddab															22	
Pacific spiny lumpsucker							20									
Pacific staghorn sculpin	43	21	64	17		43	20			35				17	22	17
Pacific tomcod														17	22	17
Padded sculpin	22	43					225	52		175						
Painted greenling																
Penpoint gunnel								17								
Plainfin midshipman	500	128	643	52	22		20		17		243		364	87	1709	1048
Pygmy poacher	196	64		17	86		122	296	34							
Red brotula																
Rex sole	22		64										17			
Rock sole		64	21	17					84						22	
Roughback sculpin	370	618	1264	845	495	22	327	417	17	210	17	17	35	70	952	821
Saddleback gunnel		21				22	41	174		17						
Sailfin sculpin										17						
Sand sole																
Shiner perch			214	69							17			52		
Slender sole	43		21								87	35	87	17	87	192
Slim sculpin	435															
Snailfish	65													17	22	
Snake prickleback			21				20									
Speckled sanddab	935	256	386	880	366	775	714	870	554	768					22	192
Spinyhead sculpin																
Starry flounder						22		70		70						
Sturgeon poacher		21		17					17							

May 2015 Fish Density

Species	EW-1	EW-2	EW-3	EW-4	EW-5	Nisqually D	S-2	S-3	S-4	T01-10E	T01-10W	T01-20E	T01-20W	T01-40W	T01-80W	T02-10N	T02-10S	T02-110	T02-20N	T02-20S	T02-40N	T02-40S
Bay goby																22					17	
Bay pipefish											22											
Big skate										19												
Blackbelly eelpout	540	997	5590	725	1176	134	518	1383	633				208	1646	1150	22		1016			592	464
Blacktip poacher														63	230							
Brown rockfish													21									
Buffalo sculpin										19		21	21	21			609	19		457		401
Butter sole																						
C-O sole										57	22		21	21					61	43	17	
Crescent gunnel													21				21			43		
Decorated warbonnet																						
English sole			35			17		33		95		63	21		42	108					34	
Flathead sole	16	17						16										19				
Fluffy sculpin																						
Great sculpin												21						19				
Grunt sculpin													21	21			21					
Longnose skate																						
Midwater eelpout			35																			
Northern spearnose poacher																						42
Pacific hake			69	69			69	16										56				
Pacific sanddab																						
Pacific staghorn sculpin													21					19				21
Pacific tomcod							17															
Padded sculpin											22		42	42	21	22	210	19		370		485
Plainfin midshipman	63	137	656	138	119		121	148	65	38		380	62	633	125	22		151	121		321	211
Pygmy poacher										38		127	104	443		151	63		182	174	508	232
Rex sole		34																				
Rock sole										19			21			22	42					42
Roughback sculpin			138		17	17	17			340	151	507	728	338	460	22	189	753	263	130	102	1731
Saddleback gunnel										19	87		42		42	22						63
Sailfin sculpin														84	21		21					42
Sand sole																						
Slender sole	48	52	276		34			66										56				
Slim sculpin														63							220	21
Snailfish													21		21			38				21
Snake prickleback				17								21										42
Soft sculpin																		19				
Speckled sanddab						50				113	87	84	83	127		194	21		202		17	148
Spinyhead sculpin															63							
Starry flounder											22											
Sturgeon poacher														21								

May 2015 Fish Density continued

Species	T02-60N	T02-60S	T02-80N	T02-80S	T03-10N	T03-10S	T03-20N	T03-20S	T03-40N	T03-40S	ZSF 2.1	ZSF 2.2	ZSF 2.3	ZSF 2.4	ZSF 2.5	ZSF 2.6
Bay goby	17															
Bay pipefish																
Big skate																
Blackbelly eelpout	2087	621	3672	3969					516		887	598	1039	554	6547	6184
Blacktip poacher	557		295												440	485
Brown rockfish																
Buffalo sculpin	17	207	169		21	19	41	70		104					17	17
Butter sole				115	21	56			1183	381						
C-O sole		21			42		104								34	52
Crescent gunnel						19										
Decorated warbonnet			21													
English sole	87	41	42	16	42	56	248	17						17	51	69
Flathead sole				16									17	17		
Fluffy sculpin							41									
Great sculpin	17														68	87
Grunt sculpin																
Longnose skate															17	
Midwater eelpout																
Northern spearnose poacher																
Pacific hake			21													
Pacific sanddab															34	17
Pacific staghorn sculpin				16							17	16		17		
Pacific tomcod			21													
Padded sculpin		83		82		56	83									
Plainfin midshipman	452	248	295	132	105		104		33	52	17	48	156	104	1844	970
Pygmy poacher	191	228		33	230	19	228	122	50	35						
Rex sole	70															
Rock sole					42	111	104	52		17						
Roughback sculpin	400	3085	317	807	481	37	663	243	533	52	17			52	474	710
Saddleback gunnel			42	49		74		330								
Sailfin sculpin	17	62	21	16												
Sand sole						19										
Slender sole	104		42								104	65	87	17	51	139
Slim sculpin	296															
Snailfish		21								17						
Snake prickleback	35			16						17						
Soft sculpin																17
Speckled sanddab	17	104	21	560	418	167	186	52	250	52		16				17
Spinyhead sculpin		41	21	16												
Starry flounder																
Sturgeon poacher						19				17						

July 2014 Fish Density

Species	EW-1	EW-2	EW-3	EW-4	EW-5	Nisqually D	S2	S3	S4	T01-10E	T01-10W	T01-20E	T01-20W	T01-40W	T01-80W	T02-10N	T02-10S	T02-110	T02-110	T02-20N	T02-20S	T02-40N	T02-40S
Big skate			43																				
Blackbelly eelpout	370	398	732	849	417	52	651	664	643				244	470	410	108		826		21		152	174
Blacktip poacher																		87				130	
Buffalo sculpin										43	17		157	17			1109				995		22
Butter sole						313				108		22											
C-O sole					17					22	17		70		16		22	43		43			
Crescent gunnel										22	87			70	16								22
Dover sole																							
English sole						17			17	22	35	87	35		16	22		43		64			
Flatfish juv.																		22					
Flathead sole				17		17																	
Great sculpin			43										17										
Grunt sculpin														35							65		43
Gunnel sp.												22	52										
Pacific sanddab			43								17												
Pacific staghorn sculpin		17			17			35	17	43	17		17	35	110	22	43	43		43	22		
Pacific tomcod						35																	
Padded sculpin											157	261	122			173	1000				1449		1196
Plainfin midshipman		52	43	121	17	17			17	22		65	17	122	79			22		64		22	
Pygmy poacher										22	35	174	52	383	284	43	43			343	216	348	261
Rex sole				17																			
Rock sole										22			35				109				65		22
Roughback sculpin						70				22	104	174	210	87	677	65	65	478	478	321	65	43	587
Saddleback gunnel											17						87	22			108		
Sailfin sculpin										65			17	17						64	108		
Sand sole																							
Scaly head sculpin													87										
Sculpin sp.																					22		
Slender sculpin																							
Slender sole			86					35															
Snailfish	22	17	86				70	35	35			22		35	205			413			22	22	848
Snake prickleback										65				17							22		
Speckled sanddab										195	87	87	175	17		195	65			236		22	22
Spiny lumpsucker													17										
Spinyhead sculpin															79			43					
Spotted ratfish																							
Sturgeon poacher						52				22	17	22	35			22							
Tiepool sculpin																							
Walleye pollock																							65

July 2014 Fish Density continued

Species	T02-60N	T02-60S	T02-80N	T02-80S	T03-10N	T03-10S	T03-20N	T03-20S	T03-40N	T03-40S	ZSF 2.1	ZSF 2.2	ZSF 2.3	ZSF 2.4	ZSF 2.5	ZSF 2.6
Big skate																
Blackbelly eelpout	1341	194	3391	213			174				518	1301	681	678	605	559
Blacktip poacher	649		696	107									17		229	
Buffalo sculpin			109		46	239	70	173								
Butter sole				256		1109	52	22	522	1478						
C-O sole					15	22	35									
Crescent gunnel						43	17	22								
Dover sole	22															
English sole		22	65	107		109	157	43	87	43	17			35	16	17
Flatfish juv.					31			130								
Flathead sole			22													
Great sculpin			43								17	68				
Grunt sculpin								22								
Gunnel sp.						65										
Pacific sanddab															33	
Pacific staghorn sculpin	22	129	87			239		260	35	43		34	35	139		70
Pacific tomcod																
Padded sculpin		387		43		43		281								
Plainfin midshipman	216		130	128	62		52		52	22			17	17	82	17
Pygmy poacher	541	301		320	279		122	87		87					16	157
Rex sole	22															
Rock sole	65	65	22			196	209	324	104							
Roughback sculpin	238	624	326	575	124		278	22	383	283				17	180	157
Saddleback gunnel	22					65		87								
Sailfin sculpin	22		87	21				22								
Sand sole							17									
Scaly head sculpin																
Sculpin sp.									17							
Slender sculpin			87													
Slender sole												68			98	70
Snailfish	43	1657	87	298							35		17	209	131	297
Snake prickleback		43	22													
Speckled sanddab					77	65	365	195	174	22						
Spiny lumpsucker																
Spinyhead sculpin																17
Spotted ratfish															33	
Sturgeon poacher				21	15		104	22	87	196						
Tiepool sculpin					31		17									
Walleye pollock													17	17		

October 2014 Fish Density

Species	EW-1	EW-2	EW-3	EW-4	EW-5	Nisqually D	S2	S3	S4	T01-10E	T01-10W	T01-20E	T01-20W	T01-40W	T01-80W	T02-10N	T02-10S	T02-110N	T02-20N	T02-20S	T02-40N	T02-40S
Bay goby																						
Bay pipefish											129		22				22					
Big skate																						
Blackbelly eelpout	383	701	1000	2000	611		835	870	591					2087	1587			2891		65	1227	197
Blacktip poacher															217			193				
Buffalo sculpin										129	321	41	22	43		22	1660	21		667		306
Butter sole						643																
C-O sole										43	107	20	44	43	22		22				22	
Crescent gunnel											21		22	22				21		65		175
English sole	17	70	43	174	17	129	35	51	70	21				43				86			215	
Flathead sole	35	18						17														
Great sculpin																	22					
Grunt sculpin												41		22			44			86		
Longnose skate																						
Pacific hake				17																		
Pacific herring																						
Pacific sanddab																		21				
Pacific spiny lumpsucker											86		22				22					
Pacific staghorn sculpin	52	35	130	17	17	171	17	17	17	21		41		304	65		66	86			452	66
Pacific tomcod	35			87		43									22							
Padded sculpin										21	64	163	328	130		175	1005			4692		1092
Pallid eelpout				17																		
Plainfin midshipman	87	70	217	174	157	64	243	273	87	43		245	87	522	543		22	236	22		65	66
Pygmy poacher										43	21	102	66	674		22	22	21	130	108	452	262
Rex sole				17																		
Rock sole										107		82									22	
Roughback sculpin		18		17		43		34		343	535	245	830	500	978	109	765	364	108	301	129	481
Saddleback gunnel										21	64		44	174	413		22	86		65	43	109
Sailfin sculpin														130						22	22	131
Sand sole																						
Sculpin sp.														109								
Sharpnose sculpin														43								
Shiner perch					17													21				
Slender sculpin		35																				
Slender sole	17			52			35	34	17									43				
Slim sculpin														43							108	
Snailfish	17		130	17		21						61		65	326		66	86		215		787
Snake prickleback	17			17	17																	22
Speckled sanddab						107				921	86	265	371	1065	65	44	197		346	172	1055	131
Spinyhead sculpin															22			21				
Starry flounder													22									
Sturgeon poacher																			22			
Unknown flatfish juv																						

October 2014 Fish Density continued

Species	T02-60N	T02-60S	T02-80N	T02-80S	T03-10N	T03-10S	T03-20N	T03-20S	T03-40N	T03-40S	ZSF 2.1	ZSF 2.2	ZSF 2.3	ZSF 2.4	ZSF 2.5	ZSF 2.6
Bay goby	22															
Bay pipefish								87								
Big skate				17												
Blackbelly eelpout	1428	303	3418	609			22		52		1548	1404	987	887	7009	5029
Blacktip poacher	498		498						35						1026	227
Buffalo sculpin		151	87	17	22	522	65	459		66					104	
Butter sole				365		130		87	1670	677						
C-O sole		22			22	65		87							52	70
Crescent gunnel		22			87		22	22								
English sole	22			122			43	22		22	70	68	52	52	70	419
Flathead sole			43			43					35		17			
Great sculpin															17	
Grunt sculpin							43									
Longnose skate															17	
Pacific hake											17	34	17	17		
Pacific herring											17					
Pacific sanddab															17	
Pacific spiny lumpsucker					22											
Pacific staghorn sculpin	151	281	195	104	22		130	22	104	87	122	103	17	139	157	262
Pacific tomcod			43								70	68	87			70
Padded sculpin		130	43	17	478	43	565	218	17	66					17	
Pallid eelpout													17			
Plainfin midshipman	519	130	454				65	22	17		157	308	173	261	3061	943
Pygmy poacher	476	216	22	174	196	174	348	218	17	22						
Rex sole																17
Rock sole	65	108			87		217		157							35
Roughback sculpin	281	1622	671	678	348	761	652	218	174	44	17		17	35	957	803
Saddleback gunnel	65					65	43	153						17	35	52
Sailfin sculpin	43		87		22		22									
Sand sole						22			17							
Sculpin sp.			22				65									
Sharpnose sculpin																
Shiner perch		22	22	17							52	34	35		52	87
Slender sculpin																
Slender sole	22										17			17	174	122
Slim sculpin	671															
Snailfish	216	1103	151	70						44		34		35	191	87
Snake prickleback			43	35					35							17
Speckled sanddab	260	87	22	157	217	370	1478	175	643	131						52
Spinyhead sculpin																17
Starry flounder						65		44								
Sturgeon poacher							22		139	131						
Unknown flatfish juv									17							

Appendix G (electronic only)

Final July 2014 Post-Cruise Summary Report
2014-15 Trawl Study at the Anderson/Ketron Island Disposal Site, Pierce County, WA

Appendix H (electronic only)

Final October 2014 Post-Cruise Summary Report 2014-15 Trawl Study at the Anderson/Ketron Island Disposal Site, Pierce County, WA

Appendix I (electronic only)

Final February 2015 Post-Cruise Summary Report 2014-15 Trawl Study at the Anderson/Ketron Island Disposal Site, Pierce County, WA

Appendix J (electronic only)

Final May 2015 Post-Cruise Summary Report 2014-15 Trawl Study at the Anderson/Ketron Island Disposal Site, Pierce County, WA