NORTHERN ABALONE, *Haliotis kamtschatkana*, STOCK STATUS AND RE-ANALYSIS OF INDEX SITE SURVEYS IN BRITISH COLUMBIA 2000-2016

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ABSTRACT

The legal harvest of Northern Abalone, *Haliotis kamtschatkana*, was closed in 1990 due to population declines and subsequent conservation concerns. Despite the closure, declines continued, leading to a legal listing of “Threatened” in 2004 and a relisting as “Endangered” in 2011 under Schedule 1 of the *Species at Risk Act* (SARA). Northern Abalone has been monitored at index sites along the East Coast of Haida Gwaii (ECHG) and the Central Coast (CC) Regions of British Columbia by Fisheries and Oceans Canada (DFO) since 1978. In response to conservation concerns, surveys were expanded to include the West Coast of Vancouver Island (WCVI) Region in 2003, the Queen Charlotte Strait (QCS) Region in 2004, and the West Coast of Haida Gwaii (WCHG) Region in 2008. This report presents survey data collected for each of these Regions since either 2000 or the initiation of the survey and includes the results of analysis using a hurdle gamma Bayesian model to examine long-term trends in the population and distribution within each Region. Some of these data have not been previously published: CC (2011, 2016), ECHG (2012), WCHG (2008, 2013), QCS (2014), and WCVI (2008, 2013). The results are presented in the context of the Population and Distribution Objectives from the Northern Abalone Action Plan.

RÉSUMÉ

La récolte légale de l’ormeau nordique, *Haliotis kamtschatkana*, a été fermée en 1990 en raison du déclin des populations et des inquiétudes que cela a entraîné quant à leur conservation. Malgré la fermeture, les déclins se sont poursuivis, ce qui a mené à l’inscription de l’espèce à la liste des espèces « menacées » de l’annexe 1 de la *Loi sur les espèces en péril* (LEP), en 2004, et à sa réinscription à titre d’espèce « en voie de disparition » en 2011. Depuis 1978, Pêches et Océans Canada (MPO) surveille l’ormeau nordique dans des sites repères le long de la côte est de Haïda Gwaii (ECHG) et de la côte centrale (CC) de la Colombie-Britannique. En réponse aux inquiétudes liées à la conservation, les relevés ont été élargis pour inclure la région de la côte ouest de l’île de Vancouver (WCVI) en 2003, la région du détroit de la Reine-Charlotte (QCS) en 2004, et la région de la côte ouest de Haïda Gwaii (WCHG) en 2008. Le présent rapport présente les données des relevés réalisés dans chacune de ces régions, soit depuis 2000 ou depuis le début de l’enquête, et comprend les résultats d’une analyse effectuée à l’aide d’un modèle bayésien gamma à obstacles pour examiner les tendances à long terme de la population et de sa répartition dans chaque région. Certaines de ces données n’ont jamais été publiées auparavant : CC (2011, 2016), ECHG (2012), WCHG (2008, 2013), QCS (2014) et WCVI (2008, 2013). Les résultats sont présentés dans le contexte des objectifs en matière de population et de répartition du Plan d’action pour l’ormeau nordique.

INTRODUCTION

The Northern Abalone, *Haliotis kamtschatkana*, is a marine mollusc that is found along exposed and semi-exposed coast lines from Alaska to Baja California (McLean 1966). The critical habitat of Northern Abalone has been well characterized and can be identified by the presence of hard substrate, Sea Urchins, certain predators and macroalgae, and the species is typically found at sites with moderate wave exposure in the low intertidal and subtidal zones at depths shallower than 15 m (Sloan and Breen 1988; Lessard and Campbell 2007).

Northern Abalone has long played an important role for coastal First Nations as a traditional food source, in making jewelry, and in trade (Menzies 2010). The First Nations fishery was primarily limited to hand picking from the intertidal zone (Sloan and Breen 1988). Prior to a ban on all harvesting in 1990, there was both a recreational and a commercial fishery for Northern Abalone in British Columbia (BC). Although little information exists on the recreational fishery, it was carried out by hand picking and via SCUBA (self-contained under water breathing apparatus), and the overall effect on the stock was considered to be minimal (Sloan and Breen 1988). Observations of commercial harvesting of Northern Abalone in BC date as far back as 1910 and harvesting occurred in both intertidal and subtidal habitats. Annual production peaked at 433 t in 1978 (Farlinger 1990). Although some population surveys were carried out before this time, index sites were established on the East Coast of Haida Gwaii (ECHG) and the Central Coast (CC) in 1978 for stock assessment purposes in order to better manage the commercial fishery. Steep declines in density (as measured at the index sites) that were attributed to recruitment failure and subsequently recruitment overfishing (Sloan and Breen 1988; Campbell 1997), led to annual reductions in the quota until 1984 where it remained stable at 47 t until the fishery was closed in 1990 (Farlinger 1990). Most of the commercial harvest of Northern Abalone was from Haida Gwaii (Pacific Fisheries Management Areas [PFMAs] 1 and 2) and the Central Coast (PFMAs 4-9). The only PFMAs with no recorded commercial harvest are 14, 16, 28, and 29 (all in the eastern Strait of Georgia). For a detailed history of the Northern Abalone fishery and its management in BC, see Sloan and Breen (1988) and Farlinger (1990).

Despite the moratorium on harvest, the density of Northern Abalone at the index sites continued to decline through the 1990s. Northern Abalone was designated as “Threatened” by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 1999 and further designated as “Endangered” in 2009. Subsequently, Northern Abalone was legally listed as “Threatened” under Schedule 1 of the *Species at Risk Act* (SARA) in 2003 and was relisted as “Endangered” in 2011. These designations and listings are based on an approximately 90% decline in the density of mature individuals in the period between 1978 and 2008 at the index sites on the CC and ECHG. Intense pressure from the commercial fishery (prior to closure in 1990), continued illegal harvest, and subsequent decreased fertilization rates due to the Allee effect (Stephens et al. 1999) have been suggested as the main cause of this decline and subsequent lack of recovery (DFO 2012).

Following the closure of the fishery and listing of the species under SARA, the "Recovery strategy for the Northern Abalone (*Haliotis kamtschatkana*) in Canada" (the "Recovery Strategy", DFO 2007) and the "Action plan for the Northern Abalone (*Haliotis kamtschatkana*) in Canada" (the "Action Plan", DFO 2012) were developed. These documents provide a number of "Population and Distribution Objectives" (PDOs), as well as required actions and potential timelines for meeting these objectives. The most recent revisions of these objectives can be found in the Action Plan. One of the key actions resulting from these documents was the expansion of the index site surveys from the CC and ECHG Regions to the West Coast Vancouver Island (WCVI) Region in 2003, the Queen Charlotte Strait (QCS) Region in 2004 and the West Coast Haida Gwaii (WCHG) Region in 2008. This report presents data collected for each of these Regions since either 2000 or the initiation of the survey in that Region. Some of these data have not been previously published: WCHG (2008, 2013), WCVI (2008, 2013), CC (2011, 2016), ECHG (2012), and QCS (2014). The results are presented in the context of the PDOs from the Action Plan.

For quick reference, the Action Plan states:

The population and distribution objectives for the recovery of Northern Abalone as adopted in the recovery strategy are:

1) *To observe that mean densities of large adult (≥ 100 mm SL) Northern Abalone do not decline below 0.1 per m^2 at surveyed index sites in Haida Gwaii and North and Central Coast, and that the percentage of surveyed index sites with large adult (≥ 100 mm SL) Northern Abalone does not decrease below 40%.*
2) *To observe that the mean total density estimates at newly established index sites in the Queen Charlotte and Johnstone Straits do not decline below the level observed in 2004 (0.06 Northern Abalone per m^2 and 0.02 Northern Abalone per m^2, respectively), and the mean total density estimates for the West Coast of Vancouver Island do not decline below the level observed in 2003 (0.09 Northern Abalone per m^2).*
3) *To observe at the index sites (in areas without Sea Otters) that the annual estimated mortality rate for mature (≥ 70 mm SL) Northern Abalone is reduced to < 0.20 and the mean densities of mature (≥ 70 mm SL) Northern Abalone are increased to ≥ 0.32 per m^2.*
4) *To observe at the index sites (in areas without Sea Otters) that the proportion of quadrats (m^2) with Northern Abalone is increased to > 40%.*

Objectives #1 and #2 are measures to monitor and halt the decline of the Northern Abalone population. Objective #1 is based on population levels in 1990, when all fisheries were closed. Objective #2 is based on the most recent population surveys (at the time the recovery strategy was developed), as a longer time series was not yet available. Objectives #3 and #4 are recovery *targets (i.e., self-sustaining population) based on the Northern Abalone population model (in Lessard et al. 2007).*

Observing an increase (> 40%) in the proportion of quadrats with a single Northern Abalone (Objective #4) is not likely to be attainable within the time frame of this action plan, as it requires current abalone occurrence to double. However, this objective provides the only measure currently available to assess changes in the patchy distribution of Northern Abalone on a fine scale.

The population and distribution objectives may be refined with improved knowledge, particularly the Northern Abalone patch size required for recruitment, and improved knowledge of the effects of Sea Otters. Currently, there is insufficient information to set population and distribution objectives for abalone in areas with Sea Otters. Once additional information is available, population and distribution objectives and recovery targets can be re-assessed and revised.

METHODS

GENERAL SURVEY DESIGN AND METHODS

Northern Abalone index site surveys are carried out in April and May each year. During this time, Northern Abalone aggregate prior to spawning and the density of annual algae species is minimal, allowing for an increased detection rate and easier, more consistent surveying of Northern Abalone (DFO 2016). Surveys are carried out by SCUBA divers from the Canadian Department of Fisheries and Oceans (DFO), in collaboration with First Nations partners.

The data presented here are from the five Regions that are regularly surveyed. Each Region is divided into smaller Areas that are made up of individual Sites. The WCHG Region is divided into three Areas: Hippa Island, Englefield Bay and Gowgaia Bay (Figure 1). The ECHG Region is divided into eight Areas: Cumshewa Inlet, Selwyn Inlet, Tanu Island, Upper Juan Perez Sound, Lower Juan Perez Sound, Skincuttle Inlet, Carpenter Bay, and Kunghit Island (Figure 2). The CC Region is divided into nine Areas: North Banks Island, Oswald Bay, Pemberton Bay, Lotbiniere Bay, North Aristazabal Island, South Aristazabal Island, Stryker Island, Simonds Group, and Spider Island (Figure 3). The QCS Region is divided into two Areas: Gordon Channel and North Queen Charlotte Strait (Figure 4). The WCVI Region is divided into four Areas: Quatsino Sound, Brooks Bay, Checleset Bay, and Kyuquot Sound (Figure 5). Regions are surveyed on a 5-year rotation, with one Region surveyed each year; the exception being WCHG and WCVI which are surveyed in the same year. Unless otherwise specified, mean values for a Region are derived from data that are pooled from all the Areas within the Region, i.e., Site is used as the primary sampling unit. It is important to note that the data presented here (and any references to the ‘population’) are specific to the index sites surveyed and may not reflect the true population of Northern Abalone within a Region.

Typically, the Canadian Coast Guard Ship *Vector* is used as a live-aboard research platform and supports two smaller dive skiffs that are used for diving operations. Efforts are made at each sampling event to revisit the same group of Sites, making them index sites. Previously sampled sites are located during each survey using chart records, written descriptions, photographs, and Global Positioning System (GPS) coordinates. Each Site is surveyed using the 'Breen' methodology (see DFO [2016] for a detailed description). Briefly, at each Site, divers place a 1 m^2 quadrat at the upper edge of Northern Abalone habitat, typically around 0 m chart datum, and sample 16 quadrats within a 7 x 16 m area (four transects separated by 4 m, each with four quadrats separated by 1 m). One deviation from the methodology described by DFO (2016) is that during DFO index site surveys, divers remove all algae from surveyed quadrats to maintain consistency in detection rates.

Historically (and in most years presented here) if no Northern Abalone were observed in the first eight quadrats, then no further quadrats were sampled and the density of Northern Abalone for the Site was recorded as zero. However, the probability of detecting the presence of Northern Abalone is higher if all 16 quadrats are surveyed (Atkins et al., 2002). Therefore, recording a Site as zero when Northern Abalone were not detected in the first eight quadrats may have resulted in under estimates of Northern Abalone prevalence and density. As such, in some Regions and years all 16 quadrats were sampled (CC 2006, 2011, 2016; ECHG 2007, 2012; QCS 2014), a practice that will be carried forward in future surveys. In each quadrat, divers record the number and size of Northern Abalone (shell length [SL] measured along the longest axis), up to three dominant substrates, up to two dominant algal species for each category of algae (canopy, understory, and turf) and the respective percent cover for each category, the number and relative size of any predator species present, and the number of Sea Urchins.

ANALYTICAL METHODS

The analyses presented here are an analysis of the previously unpublished data described in the Introduction, as well as a re-analysis of the data collected since 2000. The year 2000 was chosen as the time cut-off because it provides the most consistency in the number of sites surveyed within each Region between years. Prior to 2000, only the CC and ECHG were regularly surveyed and the number of sites surveyed and the sampling interval were much more variable (Atkins et al. 2004; Lessard et al. 2007). This period also encompasses the surveys immediately prior to the development of the Recovery Strategy and the Action Plan, the results of which were used to frame some of the PDOs.

Observed and estimated mean densities of Northern Abalone are reported for several size classes based on SL: 'All' (≥ 20 mm), 'Juvenile' (≥ 20 mm and < 70 mm), 'Adult' (≥ 70 mm), and 'Large' (≥ 100 mm). 'All' represents the density of all Northern

Abalone that were measured. ‘Juvenile’ Northern Abalone are those which are not yet likely to be sexually mature. ‘Adult’ Northern Abalone are those where 100% are likely to be sexually mature (Campbell et al. 2003). ‘Large’ Northern Abalone (previously referred to as ‘Legal’) are those that were above the legal size when the fishery was open, and also have substantially greater fecundity than smaller sexually mature Northern Abalone (Campbell et al. 2003). In contrast to previous reports, for all of the Regions, except WCHG and QCS, only Northern Abalone ≥ 20 mm have been included in the analysis due to differences in search efficiency over the years. Since about 2004, divers have been spending more time searching for hard to detect, small Northern Abalone. For total observed densities, including Northern Abalone < 20 mm, see the Appendices at the end of this report. Northern Abalone < 20 mm have been included in the data analysis for the WCHG and QCS since these surveys were initiated after the increased search effort had begun, and including these individuals may provide a better indication of settlement and early juvenile survival dynamics in these Regions. Following from previous reports and the PDOs in the Action Plan, the observed and estimated mean percentage of quadrats surveyed that contain at least one Northern Abalone, the observed percentage of Sites surveyed with at least one Large Northern Abalone, and the size frequency distributions and corresponding descriptive statistics for Northern Abalone that were measured during the surveys are also reported. Instantaneous annual mortality rates (Z) of Adult Northern Abalone were estimated for the CC and ECHG Regions based on observed density estimates and SLs from surveys conducted since the closure of the fishery in 1990 using the population model of Zhang et al. (2007). Values of Z therefore represent the instantaneous annual mortality rate from 1990 until the year indicated. This model uses average values for growth rate (K) and asymptotic length (L_∞) from published studies on Northern Abalone. In order to provide context for the possible range of Z values that may result from the wide range of published K and L_∞ values, estimated instantaneous annual mortality rates are presented using the K and L_∞ from each of these studies (Schnute and Fournier 1980; Breen 1986).

Statistical Analysis

1. Hurdle Gamma Model

A hurdle gamma model was applied to estimate Northern Abalone densities. This model is composed of a mixture of two statistical sub-models: binomial and gamma. The binomial distribution is used to model probabilities of observing non-zero densities in a survey Site, while the gamma distribution is used to model variations of non-zero densities in different Sites of a studied Area or Region.

a. For Region without Area stratification

$$\begin{cases} N_y \sim Binomial(p_y, \; TN_y) \\ D_{y,i} \sim Gamma(s_y, \; v) \end{cases} \qquad (1)$$

where N is the number of survey Sites with at least one Abalone observation, TN is the total number of surveyed Sites, and p is the probability of the presence of Abalone at one Site; D is an observed non-zero density, s and v are, respectively, the parameters of shape and rate for the gamma distribution, and the subscripts, y and i, refer to Year and Site, respectively.

The probability, p, is assumed to vary in different survey years, and is associated with the Year effect through the Logit link function:

$$\mathrm{Logit}(p_y) = \alpha + \mathrm{E}_y \tag{2}$$

where α is the intercept and E measures effect of Year on p. A prior of a vague normal distribution was assigned for α: $\alpha \sim Normal\left(0,32^2\right)$. A hierarchical prior was used to model effects of Year: $\mathrm{E}_y \sim Normal(0,\sigma_1^2)$ where σ_1 was assigned a uniform distribution between 0 and 10.

Model-expected non-zero density in Year y was linked to the Year effect through the Log function:

$$\log\left(\hat{D}_y\right) = \beta + \Phi_y \tag{3}$$

where β is the intercept and Φ measures effect of Year on $\hat{D}$. A prior of a vague normal distribution was assigned for β: $\beta \sim Normal\left(0,32^2\right)$. A hierarchical prior was used to model effects of Year: $\Phi_y \sim Normal(0,\sigma_2^2)$ where σ_2 was assigned a uniform distribution between 0 and 10.

The rate parameter for the gamma distribution was assigned a prior of a vague gamma distribution: $v \sim gamma(0.001,0.001)$. The parameter of shape for the gamma distribution was calculated as:

$$s_y = \hat{D}_y \times v \tag{4}$$

The overall mean density for Year y is:

$$\hat{\mathrm{O}}_y = \hat{D}_y \times p_y \tag{5}$$

b. For Region with Area stratification

$$\begin{cases} N_{y,j} \sim Binomial(p_{y,j}, \quad TN_{y,j}) \\ D_{y,j,i} \sim Gamma(s_{y,j}, \quad v) \end{cases} \tag{6}$$

where N is the number of survey Sites where, at least, one Abalone was observed, TN is the total number of surveyed Sites, and p is the probability of presence of Abalone at one Site; D is an observed non-zero density, s and v are, respectively, the parameters of shape and rate for the gamma distribution, the subscripts, y, j and i, refer to Year, Area, and Site, respectively.

The probability, p, is associated with the Year and Area effects through the Logit link function:

$$\mathrm{Logit}(p_{y,j}) = \alpha + \mathrm{E}_y + H_j + EH_{y,j} \qquad (7)$$

where α is the intercept, E is the effect of Year on p, H is the effect of Area on p, and EH is the effect of interaction between Year and Area on p. A prior of a vague normal distribution was assigned for α: $\alpha \sim Normal\left(0,32^2\right)$. Hierarchical priors were used to model effects of Year and Area: $\mathrm{E}_y \sim Normal(0,\sigma_1^2)$ and $H_y \sim Normal(0,\sigma_2^2)$ where σ_1 and σ_2 were each assigned a uniform distribution between 0 and 10. A hierarchical prior was used to model effect of interaction between Year and Area: $EH_{y,j} \sim Normal(0,\sigma_3^2)$ where σ_3 was assigned a uniform distribution between 0 and 10.

Model-expected non-zero density in Year y and Area j was linked to the Year and Area effects through the Log function:

$$\log\left(\hat{D}_{y,j}\right) = \beta + \Phi_y + \Psi_j + \Phi\Psi_{y,j} \qquad (8)$$

where β is the intercept and Φ measures effect of Year on $\hat{D}$, Ψ is the effect of Area on $\hat{D}$, and $\Phi\Psi$ is the effect of interaction between Year and Area on $\hat{D}$. A prior of a vague normal distribution was assigned for β: $\beta \sim Normal\left(0,32^2\right)$. Hierarchical priors were used to model effects of Year and Area: $\Phi_y \sim Normal(0,\sigma_4^2)$ and $\Psi_y \sim Normal(0,\sigma_5^2)$ where σ_4 and σ_5 were each assigned a uniform distribution between 0 and 10. A hierarchical prior was used to model effect of interaction between Year and Area: $\Phi\Psi_{y,j} \sim Normal(0,\sigma_6^2)$ where σ_6 was assigned a uniform distribution between 0 and 10.

The parameter of rate for the gamma distribution was assigned a prior of a vague gamma distribution: $v \sim gamma(0.001,0.001)$. The parameter of shape for the gamma distribution was calculated as:

$$s_{y,j} = \hat{D}_{y,j} \times v \qquad (9)$$

The overall mean density for Year y in Area j is:

$$\hat{\mathrm{O}}_{y,j} = \hat{D}_{y,j} \times p_{y,j} \qquad (10)$$

2. Hierarchical Binomial Model

The following model was used to estimate the proportions of quadrats containing Abalone for a given survey year:

$$n_i \sim Binomial(\rho_{i,} tn_i) \tag{11}$$

where the subscript, i, denotes a Site, n is the number of quadrats containing Abalone in Site i, tn is the number of quadrats surveyed in Site i, and ρ is the probability of a quadrat containing Abalone in a location around this Site. A hierarchical prior was assigned for ρ through the logit function: $\theta_i \sim Normal(\mu, \sigma^2)$ where $\theta_i = \mathrm{Logit}(\rho_i)$. μ was assigned a hyper prior of a vague normal distribution: $\mu \sim Normal(0, 32^2)$, and σ was assigned a hyper prior of a vague gamma distribution: $\sigma \sim gamma(0.001, 0.001)$.

The model-expected proportion ($\hat{P}$) of quadrats containing Abalone was calculated as:

$$\hat{P} = \sum_{i=1}^{NS} \rho_i \Big/ NS \tag{12}$$

where NS is the number of sites surveyed for the given survey year.

3. Model Runs

The JAGS software program (Plummer, 2015) was used for the Bayesian analyses. Two chains were used for each model run. The first 10,000 MCMC samples were treated as a burn-in period and thus discarded. To reduce autocorrelation, every 10th sample from the posterior distribution was selected and saved from each chain after the burn-in period. Altogether, 10,000 posterior samples were obtained from the two chains. Evidence of convergence was warranted, as the ratio of the pooled posterior variance to the average within-sample variance deviated little from one.

4. Significance

Estimated values (posterior means) were determined to be significantly (alpha = 0.05) different from a given value (such as a particular PDO) if the lower limit of the 95% credible interval (CI) was above the value or the upper limit of the 95% CI was below the value. Accordingly, values that fell within the 95% CI were determined to not be significantly different from the estimated value. Specific probabilities of whether the estimated values were different from a given value are available, but not presented here for ease of interpretation.

RESULTS AND DISCUSSION

WEST COAST HAIDA GWAII (WCHG)

Mean observed density (OD) showed an increasing trend between 2008 and 2013 at the WCHG index sites when Area was used as the sampling unit (Figure 6; Table 1). A similar pattern was also observed when Site was used as the sampling unit (thereby weighting OD values by the number of Sites within that Area; Table 2). During this period, the Regional OD of Juvenile Northern Abalone nearly doubled, and the Regional OD of Adult Northern Abalone displayed a nearly 5-fold increase, however densities for Adults were low relative to Juveniles. Additionally, in 2008, no Large (≥ 100 mm SL) Northern Abalone were observed, whereas in 2013, Large Northern Abalone were observed in each Area surveyed (Table 2). Although the magnitude of these trends varied between Areas and size classes within the WCHG Region, the overall trend of increased OD was consistent, with the exception of the Juvenile size class in Gowgaia Bay, which showed a decreasing trend in OD (Table 2).

While the ODs provide some idea of the population trends, due to the number of observed zero values, especially for the Adult and Large size classes, the hurdle gamma model used to generate the estimated mean density (ED) may better reflect the Regional and Area specific densities of Northern Abalone at the index sites on the WCHG (Ntzoufras 2009). The ODs and EDs showed a similar pattern and the ODs fell within the 95% CIs of the EDs (Figure 7). There was a trend towards increased ED of the All size class between 2008 and 2013 that was reflected in a significant positive difference between density estimates for 2013 and 2008 (Figure 8). The density difference (DD) is likely a better means of determining changes in density than comparing ODs or EDs because it takes into account the uncertainty associated with both the 2008 and the 2013 estimate of density. Although each Area showed a positive trend in the DD, the Regional value was primarily driven by the DD for Englefield Bay, which was the only Area where the DD was significantly greater than zero. Trends in density of the All size class of Northern Abalone provide a general indication of the status of the population at the index sites. While the density of the All size class increased between 2008 and 2013, due to differences in mortality rate (Sloan and Breen 1988; Zhang et al. 2007) and other factors, the density of individual size classes did not contribute to total density equally.

Juvenile density is an approximate indicator of future recruitment to the Adult portion of the population in 4-6 years. Similar to the All size class, there was also a trend towards increased ED of Juvenile Northern Abalone between 2008 and 2013 for the WCHG Region. However, although the DD was positive, it was not significantly different from zero. Contributions to this trend varied by Area. For example, the ED of Juvenile Northern Abalone for Gowgaia Bay decreased between 2008 and 2013, but the DD was not significantly different from zero. At the index sites on Hippa Island in 2008 and 2013 the EDs of Juvenile Northern Abalone were similar and the DD was not significantly different from zero. In contrast, the ED of Juvenile Northern Abalone at Sites in Englefield Bay in 2013 was more than double that of 2008, resulting in a significantly positive DD. Settlement rate and juvenile mortality in Abalone are poorly understood and are thought to fluctuate greatly with changes in oceanographic conditions (Sloan and Breen 1988). Further research is needed to understand these relationships.

WCHG is a Region that is not inhabited by Sea Otters, *Enhydra lutris*. As such, PDO #3 that the “mean densities of mature (≥ 70 mm SL) Northern Abalone are increased to ≥ 0.32 ind m^{-2}”, may be applicable and provides an indication of reproductive potential. However, it is important to note that when the PDOs were developed, the population dynamics of Northern Abalone in the WCHG Region were poorly understood, and remain so, potentially limiting the applicability of the PDOs. In 2008, the ED of Adult Northern Abalone was significantly below 0.32 ind m^{-2} (Figure 7). Between 2008 and 2013, there was a significantly positive DD (Figure 8) that is reflected in a density of Adult Northern Abalone in 2013 that was not significantly different from 0.32 ind m^{-2}. However, trends in the change in ED between 2008 and 2013 were not consistent among Areas. The ED of Adult Northern Abalone in Englefield Bay was significantly below 0.32 ind m^{-2} in 2008 and 2013, and the DD was not significantly different from zero. While the mean ED of Adult Northern Abalone at Hippa Island increased between 2008 and 2013, the DD was not significantly different from zero. The Adult size class of Northern Abalone in Gowgaia Bay showed a significant positive DD between 2008 and 2013, and in 2013 the ED was significantly above 0.32 ind m^{-2}. Hence, at the Area level, only Gowgaia Bay showed significant increases in Adult Northern Abalone densities. Due to the absence of Large Northern Abalone in 2008 and the low number of observations in 2013, it was not possible to generate EDs or DDs for this size class in the WCHG Region.

Adult density is a function of recruitment and mortality. Estimating mortality of Northern Abalone relies on accurate estimates of the growth rate coefficient and asymptotic size. There is anecdotal evidence that Northern Abalone on the WCHG grow slower and reach a smaller asymptotic size than in other Regions, as is typically of Northern Abalone inhabiting locations with high levels of wave exposure (Campbell et al. 2003). High levels of wave exposure and intensity are known to reduce algal canopy cover in the shallow sublittoral zone (Graham 1997). High levels of wave exposure on WCHG are therefore corroborated by the low levels of algal canopy cover observed relative to other Regions of the BC Coast. Due to the lack of a population model specific to the WCHG and the questionable applicability of existing models from other Regions (Zhang et al. 2007), further research is required to determine how recruitment and mortality interact to affect Adult density in the WCHG Region.

Increases in OD and ED were reflected in both the observed percentage of quadrats (OPQ; Table 3) and the estimated percentage of quadrats (EPQ) containing Northern Abalone (Figure 9). Population and Distribution Objective #4 is that “the proportion of quadrats (m^2) with Northern Abalone is increased to > 40%”. In 2008, the EPQ with Northern Abalone for the WCHG Region was significantly below 40%. When each Area was considered separately the EPQ for Gowgaia Bay was significantly below 40%, but the EPQs for Hippa Island and Englefield Bay were not significantly different than 40%. In the 2013 survey, for the WCHG Region, as well as for each individual Area, the EPQ was significantly above 40%. Notably, the EPQ with Northern Abalone for Englefield Bay nearly doubled between 2008 and 2013, reaching a maximum estimated mean of 64.8% of the quadrats containing Northern Abalone. Whether the OPQ and EPQ containing Northern Abalone is the result of habitat variability (increased number of hiding places in certain quadrats, increased food supply, etc.) or active mate searching behavior is unclear. Aggregation in Abalone increases reproductive success beyond that which would be expected based on a random or uniform distribution, particularly when densities are low (Zhang 2008; Catton and Rogers-Bennett 2013). Future work should seek to incorporate aggregative behaviour to better understand how the patchy nature of Abalone distributions affects population dynamics and recovery potential.

The number of eggs produced per female and in turn, the potential reproductive output of Northern Abalone increases exponentially after approximately 100 mm SL (Campbell et al. 2003). This relationship holds, regardless of slower growth rates in more exposed areas (Campbell et al. 2003). The percentage of Sites with Large Northern Abalone therefore provides an indication of how broadly this highly fecund portion of the population is distributed, which in turn may serve as a proxy for reproductive output. In 2008, Large Northern Abalone were not observed at any of the index sites. In 2013, Large Northern Abalone were observed at 10.4 ± 3.7% (mean ± SE) of the index sites surveyed (Table 4). By Area, Large Northern Abalone were observed at 7.7, 17.6, and 5.9% of the Sites at Hippa Island, Englefield Bay, and Gowgaia Bay, respectively.

Size frequency data provide an indication of the settlement (contribution to the Juvenile size class) and recruitment (contribution to the Adult size class) in the years preceding the survey, and potential recruitment in subsequent years. Between 2008 and 2013, the size frequency distribution of Northern Abalone (Figure 10) observed at the index sites in the WCHG Region showed a marked shift towards smaller individuals. This shift was primarily driven by a sharp increase in the number of small animals observed at the Sites in Englefield Bay (Figure 11), which resulted in the median SL decreasing from 43.5 to 17 mm in this Area (Table 5). In contrast, the Sites in Gowgaia Bay contained a greater proportion of larger individuals relative to the other Areas (median SL = 51 mm) in 2008, and shifted further in 2013 to a median SL of 71 mm. Based on the coast-wide range of published pairs of K and L_∞ values (Schnute and Fournier 1980; Breen 1986) and the von Bertalanffy growth equation (Sloan and Breen 1988), we estimate that on average, Northern Abalone will reach mean shell lengths of approximately 20-30 and 40-50 mm in their first and second years of growth, respectively. However, the mean coast-wide growth curve probably overestimates K and L_∞ for the WCHG region, and the above estimates of length-at-age for 1 and 2 year old Northern Abalone should be interpreted with caution. Individuals that were approximately 1 and 2 years old were observed in each of the Areas surveyed indicating that settlement has been occurring. Although there are some gaps, the lack of missing cohorts in the Juvenile (< 70 mm) range of the size frequency distributions can be interpreted to mean that there have been no recent settlement failures (Sloan and Breen 1988; Shepherd and Brown 1993). The proportion of the population made up of 1 and 2 year olds differed by Area suggesting that settlement rates were not spatially consistent. Sites in Englefield Bay showed a high abundance of 1 and 2 year old Northern Abalone in 2008 and an even higher abundance in 2013. In contrast, abundances were much lower in 2008 and 2013 for Hippa Island and Gowgaia Bay. Due to the spatially and temporally patchy nature of Abalone populations, settlement rates likely vary at the Area, Site, or even microhabitat level (Shepherd and Brown 1993) and high rates of settlement may only occur sporadically as is common for many species of Abalone (Sloan and Breen 1988). Because the methods used here do not directly quantify settlement rate, the difficulty in detecting small Northern Abalone, and the lack of a growth curve specific to the WCHG, the magnitude of settlement events cannot be quantitatively determined. The large proportions of the population that were just under 70 mm at Hippa Island and Gowgaia Bay in 2013 (Figure 8) are consistent with higher settlement rates occurring in the former than in the latter portion of the preceding survey interval. This observation further highlights the spatially and temporally sporadic nature of settlement rates in Northern Abalone. The size frequency distributions also show that recruitment to the adult population has been occurring and is corroborated by the 4-fold increase in Regional Adult density between the two surveys. While these results provide a rough indication of the population dynamics for WCHG, to determine the population trajectory and the recovery potential, the rate of recruitment to the Adult population and in turn a Region-specific mortality rate will likely be required.

Summaries of each dive conducted in 2008 and 2013 are provided in Appendices 1 and 2, respectively. These Appendices also provide the total number of Northern Abalone that were observed, including those not measured, within the quadrats sampled for each transect and the number and density of Sea Urchins, primarily Red Sea Urchins (*Strongylocentrotus franciscanus*). Habitat descriptions for the entire Site, including information on the substrate types and algal species observed at each Site surveyed for 2008 and 2013 are provided in Appendices 3 and 4, respectively. Data collected for habitat variables on a quadrat-by-quadrat basis per DFO (2016) are available, but not presented or analyzed here.

EAST COAST HAIDA GWAII (ECHG)

Between 1979 and 1984, the OD of Northern Abalone in the ECHG Region displayed a nearly 5-fold decline (Hankewich et al. 2008). Following this decline, density fluctuated, but remained low until 2002, despite a complete moratorium on harvest beginning in 1990. However, between 2007 and 2012, the OD of the All size class of Northern Abalone more than doubled, reaching the highest levels observed since 1984 (Table 6, Figure 12). During this period, the OD of the Juvenile, Adult, and Large size classes for the ECHG Region all showed a similar pattern, displaying an approximately 2-fold increase in density. With the exception of Tanu Island, an increase in the OD of the All size class was observed for all Areas in the Region between 2007 and 2012 (Table 7). The increase in OD in the All size class was driven by increases in both the Juvenile and the Adult size classes. For the Adult size class, at Tanu Island and Lower Juan Perez Sound a decrease in OD was observed, whereas the OD in the remaining Areas increased to varying degrees. For example, the OD of Adult Northern Abalone at Sites in Carpenter Bay, increased from 0.057 ± 0.026 ind m^{-2} to 0.523 ± 0.153 ind m^{-2}, an over 9-fold increase, whereas for Sites in Upper Juan Perez Sound, the increase was less than 2-fold. Overall, Large Northern Abalone were scarce, but there was an increase in the OD for all Areas, except Lower Juan Perez Sound, where Large individuals were absent in 2012. Although there was a general trend towards increased

OD for the ECHG Region between 2007 and 2012, the magnitude of these increases was not consistent between Areas and size classes.

While the ODs increased during the 2002 to 2012 period, low mean ODs and a large number of zero values, particularly in the Adult and Large size classes in 2002 and 2007, make comparisons of these values difficult. In all cases, the EDs showed good correspondence to the ODs, with the ODs falling within the 95% CIs of the models (Figure 13). From 2002 to 2012, the ED of the All size class for the ECHG Region doubled (Figure 13), corresponding to a DD that was significantly greater than zero (Figure 14). Although there was a slight increase in ED and a non-significant positive DD between 2002 and 2007, the change between 2002 and 2012 was primarily attributable to the large increase in the ED and the corresponding DD observed between 2007 and 2012. The mean ED for all Areas throughout the Region showed an increase in the ED of the All size class between 2002 and 2012. Despite this trend, when each Area was examined separately, only Selwyn Inlet, Upper Juan Perez Sound, and Skincuttle Inlet showed significantly positive DDs (Figure 14). The high degree of variation in the ED for a given Area points to an inconsistency in response among Sites within an Area. Further examination of the ODs for 2007 and 2012 (Hankewich et al. 2008; Appendix 5) at individual Sites within an Area revealed that while some Sites are showing large increases in OD, others are showing more moderate increases or are even declining. For example in Skincuttle Inlet, Site 28 showed an increase from a mean of 0.25 ind m^{-2} to 4.75 ind m^{-2}, whereas Site 35 declined from 0.13 ind m^{-2} to 0.06 ind m^{-2}. It is important to note that Northern Abalone were not observed at Sites in Cumshewa Inlet in 2002 or 2007 and only 9 Northern Abalone of any size were observed at these sites in 2012. These low densities prevented EDs or DDs from being generated. The variation observed within the Region and within each Area is consistent with the small scale spatial patchiness commonly reported for other Abalone populations (Sloan and Breen 1988).

For the ECHG Region, the ED of the Juvenile size class showed successive increases in 2007 and 2012 (Figure 13). Correspondingly, the DD was positive but not significantly greater than zero between 2002 and 2007, and was significantly greater than zero between 2007 and 2012, resulting in an overall DD that was significantly greater than zero (Figure 14). On an Area basis, with the exception of Tanu Island and Carpenter Bay, where the EDs for the Juvenile size class did not change from 2002 to 2012, the EDs in the remainder of the Areas increased over this period. Along with the spatial patchiness highlighted by the high level of variation between Areas and between Sites within Areas for the All size class of Northern Abalone, the variation observed for the Juvenile size class in the ECHG Region is consistent with the spatially patchy and temporally episodic nature of settlement events previously reported for other species of Abalone (Shepherd and Brown 1993).

Mean EDs of Adult Northern Abalone at Sites in the ECHG Region were similar between 2002 and 2007 (Figure 13) but displayed an increase between 2007 and 2012 that corresponded to a significantly positive DD (Figure 14). For the ECHG Region, PDO #3 states that "…the mean densities of mature (≥ 70 mm SL) Northern Abalone are increased to ≥ 0.32 ind m^{-2}." Regionally, as of 2012, the ED of Adult Northern Abalone was not significantly different from 0.32 ind m^{-2}. On an Area basis, Cumshewa Inlet and Lower Juan Perez Sound had EDs significantly below 0.32 ind m^{-2}. In contrast, the Sites at Carpenter Bay and Kunghit Island displayed large positive DDs between 2007 and 2012, and the ED for Kunghit Island was significantly greater than 0.32 ind m^{-2} in 2012.

The ED of Large Northern Abalone for the ECHG Region remains low relative to ODs in the early years of the fishery (Hankewich et al. 2008). The first half of PDO # 1 is "To observe that mean densities of large adult (≥ 100 mm SL) Northern Abalone do not decline below 0.1 ind m^{-2} at index sites in Haida Gwaii…" Beginning in 2002, both the ODs and EDs fell below this level and have remained there. However, between 2007 and 2012 the ED of Large Northern Abalone for the Region increased, albeit not to 0.1 ind m^{-2} (Figure 13), and there was a slightly positive DD (Figure 14). Estimated densities of Large Northern Abalone varied by Area. In 2012, EDs at Tanu Island, Skincuttle Inlet, Carpenter Bay, and Kunghit Island were not significantly below 0.1 ind m^{-2}. Large Northern Abalone were either scarce or absent from Cumshewa Inlet, Selwyn Inlet, and Lower Juan Perez Sound between 2002 and 2012, so EDs and DDs were not estimated. Along with decreases in OD, since the early years of the fishery, the percentage of Sites with Large Northern Abalone has shown a relatively continuous decline (Hankewich et al. 2008). The second half of PDO # 1 is "… that the percentage of surveyed index sites with large adult (≥ 100 mm SL) Northern Abalone does not decrease below 40%." By 2007, using two times the standard error as an approximation of the 95% confidence interval of the mean, the percentage of Sites with Large Northern Abalone had fallen significantly below 40% (Table 8). However, between 2007 and 2012, the percentage of Sites with Large Northern Abalone increased to 30.2 ± 17.4 (mean ± 95% confidence interval) and was no longer significantly below 40%.

At the height of the Northern Abalone fishery in 1978, > 60% of the quadrats surveyed at the index sites on ECHG contained at least one Northern Abalone. At the closure of the fishery in 1990, the OPQ with Northern Abalone had declined to nearly 30% (Hankewich et al., 2008) and further declined to about 20% by 2002 and the EPQ was also approximately 20% (Table 9; Figure 15). In 2007, the EPQ began to increase (Figure 15). Population and Distribution Objective # 4 is "To observe at the index sites (in areas without Sea Otters) that the proportion of quadrats (m^{-2}) with Northern Abalone is increased to > 40%." Although in 2012 the EPQ had not exceeded 40%, it was also not significantly different from 40% and on an Area basis, Upper and Lower Juan Perez Sound, Skincuttle Inlet, and Kunghit Island all had EPQs that were significantly greater than 40%. Further inspection of the data showed that the observed increase in the EPQ was primarily attributable to the large increases in the OD of Juvenile Northern Abalone and subsequent dispersion at the Regional, Area, and Site level.

From 1979 until 2012, the mean and median SL of Northern Abalone at Sites in the ECHG Region decreased and remained low relative to mean and median SL during the early years of the fishery (Hankewich et al. 2008; Table 10). Following initial declines in OD, the OD of Juvenile Northern Abalone remained at relatively consistent (albeit low) levels from 1984 until 2007, whereas Adult OD continued to decline, resulting in a decrease in mean and median SL. In 2012, the OD and ED of Adult and Juvenile Northern Abalone increased relative to the 2002 levels, but the increase in OD and ED for Juveniles was disproportionately high, causing the mean and the median SL to remain low. Historically, the mode of the SL size-frequency distribution in the ECHG Region has either been above or centered on the length at maturity (70 mm) (Hankewich et al. 2008; Figure 16). These observations support the hypothesis that settlement rate and juvenile survival were low prior to 2007. However, in 2007 and 2012, the distributions were skewed towards smaller sizes (Figure 16). The scarcity of Northern Abalone in 2002 makes it difficult to make inferences about the population structure for individual Areas (Figure 17). However, during the 2002 survey, Northern Abalone were not observed at Sites in Cumshewa Inlet, and in Selwyn Inlet Northern Abalone < 40 mm were not observed. Based on these observations, we hypothesize that settlement failure may have occurred in the 1-2 years prior to the survey. In the remainder of the Areas Northern Abalone < 40 mm were recorded, indicating that settlement events had occurred, though likely at a low rate. In 2007, both the count and proportion of Northern Abalone < 40 mm began to increase for many, but not all, Areas (Figure 17). By 2012, with the exception of Sites at Cumshewa Inlet and Tanu Island, both the counts and the proportion of the population < 40 mm had increased in all Areas. Although increases in settlement events were observed in the ECHG Region, the variability in population structure between Areas and years for 2007 and 2012 could be explained by a stock-recruitment relationship that varies spatially and temporally. Alternatively, previous work in other species of Abalone has suggested that above a relatively low threshold density, there may be no direct stock-recruitment relationship and factors such as oceanographic conditions may have a larger effect on settlement rates (Shepherd and Brown, 1993; McShane 1995).

The current Northern Abalone population model for ECHG (Zhang et al. 2007) estimates that an instantaneous annual mortality rate (*Z*) of 0.2-0.25 ¯y would be required to maintain the current population density. Values for *Z* < 0.2 ¯y would result in a population increase, whereas values > 0.25 ¯y would result in population declines. Based on this information, the first criterion in PDO # 3 is “To observe at index sites (in areas without Sea Otters) that the annual estimated mortality rate for mature (≥ 70mm SL) Northern Abalone is reduced to < 0.20 [¯y]…” Corresponding to the observed increases in density, *Z* for the ECHG has been declining. Between 2002 and 2007, *Z* declined from a mean of 0.36 ± 0.065 ¯y (Zhang et al., 2007) to 0.28 ± 0.04 ¯y (Hankewich et al., 2008). In 2012, using the same parameters, *Z* was estimated to be 0.252 ± 0.016 ¯y. Despite an increase in the OD and ED of Adult Northern Abalone, the 2012 estimate of *Z* remained > 0.2 ¯y. However, when the model is re-run using the range of values for asymptotic length (L_∞) and growth rate (*K*) from the literature, rather than the mean, estimates of Z vary between 0.151 ± 0.010 ¯y and 0.273 ± 0.019 ¯y (Table 11). Since L_∞ and *K* vary with habitat conditions (Breen 1986; Emmett and Jamieson 1988), the use of the mean literature values for L_∞ and *K* may bias estimates of Z at the ECHG index sites. Although the magnitude and direction of this bias is unknown, given that OD and ED are increasing despite our estimated value for *Z* being

> 0.25 ‾y, it is likely that the true value of Z lies somewhere below the estimate generated.

Dive summaries from the 2012 ECHG Northern Abalone survey are presented in Appendix 5. Along with the dive parameters for each Site surveyed, this Appendix also presents the number of Northern Abalone that were observed, but not measured. Typically, all of the Northern Abalone in a quadrat would be measured, but occasionally individuals could be seen, but were inaccessible and could not be measured. Therefore, the ODs and subsequently the EDs presented here may be slightly conservative as only Northern Abalone that were measured were included in the analyses. For each Site surveyed in 2012, Appendix 6 provides habitat descriptions for the entire Site, including substrate, dominant algal species and percent cover. Habitat data collected on a quadrat-by-quadrat basis as per DFO (2016) is available, but is not presented or analyzed here.

CENTRAL COAST (CC)

Following years of decline (Hankewich and Lessard 2008), the OD of the All size class of Northern Abalone at Sites on the CC of BC began to increase beginning in 2001 and continuing through the most recent survey (2016). In 2016, the OD of the All size class of Northern Abalone was over seven-fold higher than values observed in 2001 (Figure 18; Table 12). Similar patterns were observed for individual size classes as well, with the density of Juvenile (> 13-fold), Adult (> 3-fold), and Large (nearly 2-fold) Northern Abalone all increasing. The magnitude and temporal pattern of the observed increases varied by size class at the Region level, with the mean OD of the Large size class decreasing between 2001 and 2006. Although there was an increase in the OD of the All size class for all Areas within the Region, the magnitude of these increases varied by Area (Table 13). For example, between 2001 and 2016, the OD of the All size class of Northern Abalone at Sites on North Banks Island increased from 0.438 ± 0.133 ind m^{-2} to 1.531 ± 0.411 ind m^{-2}, whereas the OD at Sites in Pemberton Bay increased from 0.219 ± 0.097 ind m^{-2} to 3.550 ± 1.194 ind m^{-2}. Changes in the OD were not consistent for each size class within an Area, particularly for bigger size classes. For example, Adult OD at Sites on Stryker Island and Large OD at Sites on Spider Island decreased between 2001 and 2016 (Table 13).

The ODs show population trends within the Region, however, due to the scarcity of Northern Abalone in 2001 and 2006, particularly for the Adult and Large size classes, the EDs and DDs generated by the hurdle gamma model may better describe the Regional and Area specific changes in the density of Northern Abalone at Sites on the CC (Ntzoufras 2009). Although the fit of the model varied, all of the ODs fell within the 95% CIs of the EDs. For the All size class, the ED for the CC Region displayed a nearly 4-fold increase between 2001 and 2016 (Figure 19), with significantly positive DDs between 2006 and 2011, and 2011 and 2016, as well as between 2001 and 2016 (Figure 20). A similar trend in the ED was observed between 2001 and 2016 for all Areas throughout the Region, with Oswald Bay, Pemberton Bay, North and South Aristazabal Island, and the Simonds Group all showing significantly positive DDs.

However, it was uncommon to observe a significantly positive DD between subsequent surveys within a given Area. For example, despite a significantly positive DD for the Region as a whole between 2006 and 2011, only Stryker Island showed a significantly positive DD for this interval. The lack of significantly positive DDs for most Areas is likely due to the high degree of variability between Sites combined with the smaller sample size, as evidenced by the broad CIs for the EDs.

The Juvenile size class at Sites in the CC Region displayed the largest increase in ED, increasing nearly 5-fold between 2001 and 2016 (Figure 19). This increase was primarily driven by large increases in density between 2011 and 2016 that were evident in the EDs in most Areas within the Region (Figure 19). Based on the DDs alone, it would appear that three Areas contributed to this increase, as between 2001 and 2016, only Pemberton Bay, South Aristazabal Island, and the Simonds Group displayed significant positive DDs for the Juvenile size class (Figure 20). However, closer inspection of the observed data showed that at least a few Sites within each Area had high densities of Juvenile Northern Abalone (Appendix 8). This finding highlights not only the high degree of between Area variability in density, but also the high degree of within Area variability in settlement patterns. The patchy and episodic nature of settlement observed in the CC Region appears to be characteristic of populations of many species of Abalone and may be a leading factor in the precarious nature of recovery (Shepherd and Brown 1993).

Increasing density in the Adult size class was observed for Sites in the CC Region with each successive survey between 2001 and 2016 (Figure 19). For this Region, PDO # 3 states that "…the mean densities of mature (≥ 70mm SL) Northern Abalone are increased to ≥ 0.32 per m^2." For both 2011 and 2016, the mean ED of Adult (mature) Northern Abalone was significantly greater than 0.32 ind m^{-2}. In 2016, three Areas (Lotbiniere Bay, Pemberton Bay and Oswald Bay) had EDs significantly above 0.32 ind m^{-2}, four (North Banks Island, North Aristazabal Island, Simonds Group and Spider Island) had EDs that were not significantly different than 0.32 ind m^{-2} and two (South Aristazabal Island and Stryker Island) had EDs significantly below 0.32 ind m^{-2} (Figure 19). However, when the DDs were examined for each Area, only Oswald Bay displayed a significant positive DD between 2001 and 2016, and there were no significant positive DDs for the period from 2001 to 2016 between each survey and the previous one (Figure 20). This finding highlights that although the ED of Adult Northern Abalone at Sites in the CC Region appears to be increasing and is corroborated by positive DDs, there remains a high degree of variability between and within Areas.

The ED for Large Northern Abalone in the CC Region remains low relative to the ODs prior to the closure of the fishery (Hankewich and Lessard 2008). However, EDs from 2006 onward have shown a slight increasing trend (Figure 19). There was a significant positive DD between 2006 and 2011, and a trend towards a positive DD between 2001 and 2016 (Figure 20). The first half of PDO #1 is "To observe that mean densities of large adult (≥ 100 mm SL) Northern Abalone do not decline below 0.1 per m^2 at index sites in Haida Gwaii and North and Central Coast,..." By 2016, the ED for Large Northern Abalone for the CC region had increased and was not significantly below 0.1 ind m^{-2}. On an Area basis, only the Sites at South Aristazabal Island, Stryker Island, and Spider Island had EDs of Large Northern Abalone that were significantly below 0.1 ind m^{-2}. Due to the general scarcity of Large Northern Abalone for certain year and Area combinations, DDs could not be generated. The second half of PDO #1 is "…that the percentage of surveyed index sites with large adult (≥ 100 mm SL) Northern Abalone does not decrease below 40%." Using two times the standard error as an approximation of the 95% confidence interval, from 2001 to 2006 the percentage of Sites with Large Northern Abalone decreased to below 40%. Following this decline and corresponding to increases in OD and ED, in 2011 and 2016 the percentage of Sites with Large Northern Abalone increased to about 40% (Table 14).

Prior to the closure of the fishery, the OPQ with at least one Northern Abalone declined from about 67% (1978) to 30% (1989) for the CC Region (Hankewich and Lessard 2008). Between 1989 and 2001, there was a further decline in the OPQ with Northern Abalone to 14.5 ± 2.0% (Table 15). From 2001 to 2016, the EPQ with at least one Northern Abalone showed a statistically significant stepwise increase with each subsequent survey (Figure 21). Population and Distribution Objective #4 is "To observe at the index sites (in areas without Sea Otters) that the proportion of quadrats (m^2) with Northern Abalone is increased to > 40%." By 2011, the EPQ with Northern Abalone in the CC Region had increased to 40% and by 2016 the EPQ with Northern Abalone was significantly greater than 40%. On an Area basis, a similar trend was observed with the EPQ increasing between 2001 and 2016, and by 2016 the EPQ with at least one Northern Abalone was significantly greater than 40% for all Areas on the CC. Further inspection of the data revealed that although Adult Northern Abalone are becoming more abundant, the observed increases in the EPQ with Abalone are primarily attributable to increases in Juvenile density and subsequent dispersion at the Area and Site level.

From 1978 until 2006, both the mean and the median SL of Northern Abalone at Sites in the CC Region decreased (Hankewich and Lessard 2008). This trend continued in 2011 and 2016 (Table 16), but the factors contributing to the decline have changed. Prior to 2006, the decrease in mean and median SLs was likely attributable to decreases in the density of the Adult portion of the population, with the density of the Juvenile portion remaining low. During this time, the mode of the distribution of SLs was centered on the median (Hankewich and Lessard 2008). Beginning in 2006, the density of Northern Abalone for the CC Region began to increase. As a result of disproportionate increases in Juvenile density, the distribution of SLs became skewed towards smaller sizes, resulting in a continued decrease in mean and median values (Table 16; Figure 22). Based on the distribution of SLs prior to 2006, some Areas of the CC may have been experiencing settlement failure, as evidenced by the scarcity of Northern Abalone < 40 mm. Settlement failure is common in Abalone populations and Sloan and Breen (1988) suggest that Northern Abalone populations in British Columbia likely would have displayed population declines due to settlement failure even in the absence of fishing. In 2001, Northern Abalone < 40 mm were scarce or absent from all Areas of the CC Region (Figure 23), which is consistent with settlement failure throughout the Region. Beginning in 2006 and in each subsequent survey year, evidence of 1-2 years of settlement was observed in most Areas within the CC Region. Interpreting trends in Abalone stock-recruitment data is notoriously difficult due to short dispersal distances, density thresholds above which stock-recruitment relationships no longer apply, and the influence of oceanographic conditions and other environmental factors (McShane 1995). However, it is clear that Northern Abalone are settling in these Areas and surviving to maturity. While increases in the density of Adult and Large Northern Abalone, as well as the percentage of Sites with Large Northern Abalone are promising for recovery, it is important to note that the maximum length of Northern Abalone observed at Sites in the CC showed a precipitous decline during the fishery (Hankewich and Lessard 2008) and has remained low despite a moratorium on harvest.

The current Northern Abalone population model for the CC (Zhang et al. 2007) estimates that a Z of 0.2 - 0.25 ¯y would be required to maintain the population at current levels. Values for Z < 2 ¯y would result in a population increase, whereas values > 0.25 ¯y would result in population declines. Based on this information, the first criterion in PDO #3 is "To observe at index sites (in areas without Sea Otters) that the annual estimated mortality rate for mature (≥ 70mm SL) Northern Abalone is reduced to < 0.20 [¯y]…" In conjunction with the observed increases in density for Adult Northern Abalone on the CC, Z has been declining. Previous reports estimated Z to be 0.36 ± 0.065 ¯y in 2001 (Zhang et al. 2007) and 0.33 ± 0.07 ¯y in 2006 (Hankewich and Lessard, 2008). In the current study, using the same parameters as these previous studies, Z was estimated to be 0.295 ± 0.023 ¯y (Table 17). It is important to note that although the density of Adult Northern Abalone is increasing and Z is declining, the estimated value of Z, according to model predictions, still falls within the range of values that should result in population declines. The growth parameters (K and L_∞), both vary with wave exposure and the mean values used to parameterize the model in previous studies do not take into account whether these values are representative of the Northern Abalone index sites in the CC Region. Accordingly, when the range of literature values for K and L_∞ are used to parameterize the model, estimates of Z vary between 0.118 ± 0.014 ¯y and 0.310 ± 0.027 ¯y (Table 17). Although the magnitude and direction of this bias is unknown, it may account for observed increases in density despite an estimated Z of > 0.25 ¯y.

Dive summaries for the 2011 and 2016 CC Northern Abalone surveys are presented in Appendices 7 and 8, respectively. Along with the dive parameters for each Site surveyed, Appendices 7 and 8 also present the number of Northern Abalone that were observed but not measured (and subsequently have not been included in the ODs described above). For 2011, there were few Northern Abalone that could not be measured, however in 2016 following the spread of sea-star wasting disease in 2012 (Hewson et al. 2014), there were few Sunflower Sea Stars (*Pycnopodia helianthoides*) present on the CC. During surveys, when Northern Abalone are lodged in crevices and cannot be measured, brushing the Northern Abalone with a Sunflower Sea Star arm causes them to release from the substrate so that they can be removed and measured. At some Sites in 2016, a large proportion of Northern Abalone were observed but could not be measured (Appendix 8), resulting in more conservative ODs and EDs for 2016. These Appendices also present the number of Sea Urchins (primarily Red Sea Urchins) that were observed at each Site. Habitat descriptions for each Site surveyed in 2011 and 2016 including substrate, dominant algal species and percent cover are presented in Appendices 9 and 10, respectively. These Appendices provide data for the entire Site; habitat data collected on a quadrat-by-quadrat basis per DFO (2016) is available, but is not presented or analyzed here.

QUEEN CHARLOTTE STRAIT (QCS)

The Northern Abalone index site survey in the QCS Region currently encompasses Sites in the Gordon Channel (GC) Area and the North Queen Charlotte Strait (NQCS) Area. However, the index sites in the GC Area provide the most relevant comparisons to the PDOs since the NQCS Area was not added until 2009, after the objectives in the Northern Abalone Action Plan were developed. For comparative purposes data from GC and NQCS are presented separately here. Relative to the CC and ECHG, Northern Abalone survey data for the QCS Region are sparse prior to 2004. There are a few index sites for which historical data are available, but the majority of historical population and distribution information has been derived from timed swims or catch records from the commercial fishery (Breen et al. 1978; Adkins 1996; Lucas et al. 2002).

Gordon Channel (GC)

Between the re-initiation of the QCS index site survey in 2004 and when Sites in GC were revisited in 2009, the OD of the All size class of Northern Abalone increased from 0.042 ± 0.020 ind m^{-2} to 0.164 ± 0.061 ind m^{-2}, a nearly 4-fold increase (Figure 24; Table 18). However, when Sites were again revisited in 2012, the OD was similar to 2009. This pattern was also observed for the Juvenile, Adult, and Large size classes, there was a pronounced increase in OD between 2004 and 2009, and then levels remained relatively similar between 2009 and 2014.

The hurdle gamma model was used generate EDs and DDs because of the low OD and the large number of zero values in the OD data, particularly for the Adult and Large size classes. The EDs showed good correspondence to the ODs, with all of the ODs falling within the 95% CIs of the EDs (Table 18; Figure 25). The only PDO for QCS is # 2: “To observe that the mean total density estimates at newly established index sites in the Queen Charlotte and Johnstone Straits do not decline below the level observed in 2004 (0.06 Northern Abalone m^{-2} and 0.02 Northern Abalone m^{-2}, respectively)…” It is important to note that the observed density in 2004 included a number of Sites that have not been revisited since the initial survey because they were part of an experimental project examining the effects of finfish aquaculture sites on Northern Abalone (Davies et al. 2006). When these Sites are excluded, the estimated density is 0.04 Northern Abalone m^{-2} and this value may better represent the mean total density at the index sites in 2004.

Between 2004 and 2009, the ED of the All size class of Northern Abalone approximately doubled and the ED in 2009 was significantly greater than the PDO of

0.06 ind m^{-2} (Figure 25). The ED in 2014 was similar, remaining above 0.06 ind m^{-2}. Despite an increase in the ED between 2004 and 2009, there was no significant positive DD between any two survey years (Figure 26). Since DD takes into account the uncertainty associated with both survey years, the lack of a positive DD may be the result of a high degree of variability between and within Sites. Further examination of the data showed that despite increases in density, in 2014, no Northern Abalone of any size were observed at 35.3% of the Sites in GC (Appendix 11). As with the ODs, the EDs for the Juvenile, Adult, and Large size classes all showed increases between 2004 and 2009, and then remained relatively stable between 2009 and 2014 (Figure 25). Similar to the All size class, none of the other size classes displayed a positive DD between any of the survey years, primarily due to high variability between and within Sites. In 2004, only 5.3% of the Sites had Large Northern Abalone (Table 19). In 2009, the percentage of Sites with Large Northern Abalone increased to 29.4% and remained there in 2014. Although the OPQ (Table 20) and EPQ containing Northern Abalone (Figure 27) are relatively low, these values more than doubled between 2004 and 2009 and remained at similar levels in 2014. An increase in the percentage of Sites with Large Northern Abalone and the EPQ with Northern Abalone suggests that the distribution of Northern Abalone both between and within Sites is becoming more uniform.

Compressed size-frequency distributions of Northern Abalone were recorded in 2004 and 2009. The smallest Northern Abalone recorded in 2004 was 56 mm and only one Northern Abalone > 100 mm was observed, and in 2009, Northern Abalone < 45 mm were not observed (Table 21). The absence of Juvenile Northern Abalone < 40 mm is consistent with little or no settlement at the index sites in the 1-2 years prior to 2004 or 2009. The increase in the number of Juvenile Northern Abalone in 2009 (Figure 28) shows that successful settlement events occurred at some point between 2004 and 2009. As a result of the increase in the observed number of small (< 40 mm) Juvenile Northern Abalone in 2014, both the mean and the median SL decreased (Table 21). Along with the increase in the OD and ED of Large Northern Abalone, there was also an increase in the maximum SL observed in 2014.

North Queen Charlotte Strait (NQCS)

An additional 15 index sites were added to the survey of the QCS Region in the NQCS Area in 2009. The criteria used to select these sites prevent direct comparisons between density estimates from GC and NQCS. The majority of Sites in both Areas were chosen randomly and then refined based on habitat criteria with no prior knowledge of the history of Northern Abalone abundance. However, some of the Sites in GC are historic index sites that were selected because they had high abundances of Northern Abalone during the commercial fishery (Davies et al. 2006). Site names beginning with an ‘R’ in Appendix 11 indicate those Sites that were randomly chosen and those beginning with an ‘I’ are historic index sites. Despite the inability to make direct comparisons between GC and NQCS, it is worth noting that with the exception of the Large size class in 2014, the OD of Northern Abalone in the All, Juvenile, Adult, and

Large size classes at Sites in NQCS were all less than half of the ODs at Sites in GC in 2009 and 2014 (Figure 29; Table 18).

Between 2009 and 2014, the ED showed little change within each size class (Figure 30). In 2009 the ED of the Adult size class was greater than the ED of the Juvenile size class and in 2014, the EDs of both the Adult and the Large size classes were greater than the Juvenile size class. Between 2009 and 2014, there was a trend towards increasing ED for the Large size class, however the DD between these two years was not significant (Figure 31). Despite no significant DD for the Large (or any other) size class, the percentage of Sites with Large Northern Abalone increased from 13.3% (2/15) in 2009 to 28.6% (4/14) in 2014 (Table 19). However, both the OPQ and the EPQ with Northern Abalone remained similar between years (Figure 32; Table 20).

Only one Northern Abalone < 45 mm was observed in 2009 and none were observed in 2014 at the index sites in NQCS (Figure 33). In contrast, between 2009 and 2014, it appears that the number of Northern Abalone ≥ 100 mm SL increased. While it is difficult to make inferences about population structure when animals are scarce (only 15 animals were observed in 2009 and 10 in 2014), based on these data we suggest that little or no settlement is occurring as the majority of the population continues to age. This idea is further supported by the mean, median, maximum, and minimum SL increasing between 2009 and 2014 (Table 21).

A dive summary for the 2014 QCS Northern Abalone survey is presented in Appendix 11. Along with dive parameters for each transect surveyed, the number of Northern Abalone that were observed but not measured (and subsequently have not been included in the ODs described above), and the number and density of Sea Urchins (primarily Red Sea Urchins) are also presented. Habitat descriptions for each Site surveyed in 2014 including substrate, dominant algal species and percent cover are presented in Appendix 12. This Appendix provides data for the entire Site; habitat data collected on a quadrat-by-quadrat basis as per DFO (2016) is available, but is not presented or analyzed here.

WEST COAST VANCOUVER ISLAND (WCVI)

Since its inception in 2003, the WCVI Northern Abalone index site survey has expanded to include additional Sites with each successive survey. Since the PDOs were developed based on the findings of the 2003 survey, the results and analyses presented here have been examined in two separate ways:

1) Sites which were repeatedly sampled since 2003, which allows for comparisons between years and;

2) All the Sites surveyed in a given year, on an Area basis, which allows for comparisons between Areas within a given year.

<u>Repeated Sites</u>

Sixteen Sites, 11 from Quatsino Sound and 5 in Brooks Bay, were repeated in each of the 2003, 2008, and 2013 surveys. The OD of each size category (All, Juvenile, Adult, and Large) at these Sites has declined in successive surveys (Figure 34; Table 22). This decline was most pronounced for the Adult size class where the OD was 9-fold lower in 2013 relative to 2003.

Due to the large number of zero values and general scarcity of Northern Abalone at these Sites, EDs and DDs were generated using a hurdle gamma model. Population and Distribution Objective #2 states that "the mean total density estimates for the West Coast of Vancouver Island do not decline below the level observed in 2003 (0.09 Northern Abalone m^{-2})". However, the mean total density estimate included a number of "Exposed" Sites around the Brooks Peninsula that did not contain Northern Abalone (Atkins and Lessard 2004). Based on recommendations from the original report, and due to unfavourable weather conditions in 2008 and 2013, these Sites have not been re-surveyed. The highly exposed locations of these Sites also make it unlikely that they will be included in future surveys. If these Sites are excluded, then the observed mean total estimated density of Northern Abalone at the index sites in 2004 was 0.18 Northern Abalone m^{-2} (Table 22). This is likely a better estimate for comparisons to subsequent observations than the 0.09 Northern Abalone m^{-2} in PDO #2. The ED for the All size class of Northern Abalone was not significantly below 0.09 ind m^{-2} in all years. However, ED also showed a successive decline over the survey period and was significantly below 0.18 ind m^{-2} in 2013 (Figure 35). The ED for the Juvenile size class remained relatively stable between 2003 and 2013. In contrast, the ED of the Adult size class declined and is likely responsible for the declines in the All size class. Despite the observed decreases, due to the variation between and within Sites the DD between years for each size class was not significantly different from zero (Figure 36). An ED and DD could not be generated for the Large size class due to the scarcity of Northern Abalone ≥ 100 mm in the surveys. In both 2003 and 2008, only 6.3% of the repeated Sites had Northern Abalone ≥ 100 mm and in 2013, Northern Abalone ≥ 100 mm were absent from all of the repeated Sites. Along with the decreases in OD and ED, the OPQ and EPQ with Northern Abalone showed a decline between 2008 and 2013 (Figure 37; Table 23).

The size frequency distributions at repeated Sites were relatively flat, and Northern Abalone were generally scarce (Figure 38). Only 47, 41, and 16 Northern Abalone were measured in 2003, 2008, and 2013, respectively (Table 24). Despite declines in the density of Adults (and presumably total fecundity), Northern Abalone < 40 mm SL were present during each survey, suggesting that some settlement had occurred in the 1-2 years prior to each survey.

<u>All Sites</u>

<u>2003</u>

In 2003, 13 Sites in Quatsino Sound and 5 Sites in Brooks Bay were surveyed. An additional 14 Exposed Sites around the Brooks peninsula were also sampled as part of this survey, but are not considered here since they have not been re-surveyed and the data are presented elsewhere (Atkins and Lessard, 2004). The OD of the All size class at Sites in Brooks Bay was five-fold less than the mean OD in Quatsino Sound (Table 25). Accordingly, the OD of the Juvenile and Adult classes were both lower in Brooks Bay than Quatsino Sound and Large sized Northern Abalone were absent from Brooks Bay.

Along with differences in the ODs between Quatsino Sound and Brooks Bay, the ED for the All size class at Sites in Quatsino Sound was greater than the ED for Sites in Brooks Bay (Figure 39), but due to the high degree of variability between Sites within each Area, a statistically significant difference could not be detected. Despite differences in the OD of the Juvenile and Adult size classes, the EDs for Quatsino Sound and Brooks Bay were also not significantly different. EDs could not be determined for the Large size class as only two Northern Abalone ≥ 100 mm SL were observed in Quatsino Sound, both at the same Site, and none were seen in Brooks Bay. In 2003, the OPQ and EPQ with Northern Abalone were 3-fold less at Sites in Brooks Bay than in Quatsino Sound (Table 26; Figure 40).

The 2003 size frequency distributions of Northern Abalone in Quatsino Sound and Brooks Bay were pooled for analysis since only 44 and 3 specimens were measured in each area, respectively (Table 27; Figure 41). The mean and median SLs (Table 27) were below the length at maturity (70 mm SL). Despite low densities of Adult Northern Abalone and Large Northern Abalone being nearly absent, individuals < 40 mm SL were observed in both Areas, which is consistent with some settlement in the 1-2 years prior to the 2003 survey (Figure 41).

2008

Sites in Quatsino Sound and Brooks Bay were again surveyed in 2008, but an additional 7 Sites in Brooks Bay (making 12 total) were surveyed in 2008 that were not surveyed in 2003. The OD for the All, Juvenile, Adult, and Large size classes were all higher in Quatsino Sound than in Brooks Bay in 2008 (Table 25).

The ED of the All size class at Sites in Quatsino Sound was higher than at Sites in Brooks Bay (Figure 39), but due to the high degree of variability between Sites within each Area, a statistically significant difference could not be detected. The EDs of the Juvenile and the Adult size classes at Sites in Quatsino Sound were higher than EDs for Sites at Brooks Bay, which means that both of these size classes likely contributed to the difference in ED for the All size class. In 2008, only one Northern Abalone ≥ 100 mm SL was observed in Quatsino Sound (interestingly, at the same Site as in 2003) and none were observed in Brooks Bay, preventing EDs from being generated for this size class. In 2008, the OPQ and EPQ were again approximately 3-fold lower in Brooks Bay than Quatsino Sound (Table 26; Figure 40).

Due to the increased number of Sites surveyed in 2008, 28 Northern Abalone were measured at Sites in Quatsino Sound and 9 in Brooks Bay (Table 27). Both the mean and median SLs for Brooks Bay and for Quatsino Sound in 2008 were below the length at maturity (70 mm SL) and these values were lower for Brooks Bay than for Quatsino Sound (Table 26). Some individuals < 40 mm were present in both Areas, though there was a conspicuous lack of individuals between 35 and 45 mm (Figure 41), which may mean that there was a period in the 1-2 years prior to the survey where little or no settlement occurred.

2013

In 2013, the WCVI Northern Abalone index site survey was expanded to include Sites in Checleset Bay (18 Sites) and Kyuqout Sound (10 Sites), as well as additional Sites in Quatsino Sound (18 Sites total) and Brooks Bay (16 Sites total). The OD of the All size class in Quatsino Sound was below and in Kyuquot Sound was above the ODs in Brooks and Checleset Bays (Table 25). The ODs of the Juvenile size class were similar for Quatsino Sound, Brooks Bay, and Checleset Bay, but the OD for Sites in Kyuquot Sound was 1.5 to 2-fold higher than the other Areas. In contrast, the ODs of Adult Northern Abalone for Quatsino Sound, Checleset Bay, and Kyuquot Sound were all similar, but less than half of that at Sites in Brooks Bay. Although Large Northern Abalone were scarce in previous years, they were completely absent from Sites in all Areas surveyed in 2013.

In contrast to trends in the OD of Northern Abalone, there were no significant differences in ED between any of the Areas for any of the size classes in 2013 (Figure 39). However, there was an increase in both the OPQ and EPQ with Northern Abalone along a north-south gradient (Table 26; Figure 40). As such, the EPQs for Checleset Bay and Kyuquot Sound were significantly greater than the EPQ for Quatsino Sound.

The maximum length of Northern Abalone observed in 2013 on the WCVI was 89 mm (Table 27). Northern Abalone ≥ 70 mm made up a small proportion of the population and the mean and the median SLs were below the length at maturity (70 mm SL). In all Areas, there were some individuals < 40 mm, which means that some settlement occurred in the 1-2 years prior to the survey (Figure 41).

Dive summaries for the 2008 and 2013 WCVI Northern Abalone surveys are presented in Appendices 13 and 14, respectively. Along with the dive parameters for each Site surveyed, Appendices 13 and 14 also present the number of Northern Abalone that were observed but not measured (and subsequently have not been included in the ODs described above). These appendices also present the number of Sea Urchins (primarily Red Sea Urchins) that were observed at each Site. It is interesting to note that at repeated Sites on WCVI Sea Urchin density declined along with the Northern Abalone density. The density of Sea Urchins declined over 6-fold between 2003 and 2008, with observed values of 0.39 ± 0.13, 0.06 ± 0.02, and 0.12 ± 0.05 ind m^{-2} (mean ± SE) in 2003, 2008, and 2013, respectively. Habitat descriptions for each Site surveyed in 2008 and 2013 including substrate, dominant algal species and percent cover are presented in Appendices 15 and 16, respectively. These Appendices provide data for the entire Site; habitat data collected on a quadrat-by-quadrat basis as per DFO (2016) is available, but is not presented or analyzed here.

CONCLUSIONS

Northern Abalone (as measured at the index sites) are showing signs of recovery in the majority of survey Regions throughout the BC coast and are moving towards the PDOs outlined in the Action Plan. Although overall densities are increasing, population structure is much different than it was historically and the scale of these changes is not consistent across Regions, Areas, and Sites.

Increases in the density of the All size class are primarily driven by increases in the density of Juvenile Northern Abalone. This increase may be related to favourable settlement conditions beginning in about 2006, as evidenced by an increase in 1-2 year old individuals at each subsequent survey point. This rebuilding scenario may have been further enhanced by reduced predation pressure due to mass mortalities of Sunflower Stars from sea-star wasting disease beginning in 2012 (Hewson et al. 2014). These increases in Juvenile density are also reflected in an increase in the percentage of quadrats with Northern Abalone, which is consistent with increased dispersion. Densities in the Adult size class remain low relative to values observed in the early years of the fishery; however the majority of Regions are showing increases in Adult density. The density of the Large size class, which has the greatest per capita contribution to the fecundity of the population (Campbell et al. 2003) is increasing, but overall remains low relative to historic values. Correspondingly, the prevalence of Large Northern Abalone (as measured by the percentage of sites with Large Northern Abalone) also appears to be showing signs of increase. The resulting differences in the size structure of the current population relative to the historic population structure are reflected in proportional size-frequencies that are shifted towards smaller juveniles and correspondingly low mean and median SLs. If the historic size structure of the population is not regained, then it will be important for future work to incorporate population-level fecundity when comparing density at the index sites to historic levels. For example, in 2012 the density of Adult Northern Abalone at the ECHG index sites was approximately 6% higher than the density observed in 1990, but we estimate that egg production was approximately 28% lower due to a smaller proportion of Large Northern Abalone within the Adult size class (Campbell et al. 1992). Based on this information, if there is a stock-recruitment relationship for Northern Abalone, it may be necessary to re-evaluate the second half of PDO #3 that “the mean densities of mature (≥ 70 mm SL) Northern Abalone are increased to ≥ 0.32 per m^2” to reflect differences in egg production due to changes in the size structure of the population.

The population model presented in the Recovery Potential Assessment (RPA) for Northern Abalone (Lessard et al. 2007) was produced using the best information available at the time. Subsequently, the model was used for the population projections in the RPA and to develop the target mortality rates used in the PDOs. However, even at that time, the authors recommended that specific growth models be produced for different habitats due to differences in growth rate and asymptotic size with varying levels of wave exposure. The von Bertalanffy growth model is at the foundation of the population model for Northern Abalone (Zhang et al. 2007). The length at age relationship produced by the von Bertalanffy growth model, and in turn the population projections and mortality estimates produced by the population model for Northern Abalone, relies on accurate growth parameters (L_∞ and K; Haddon 2011) that are reflective of the conditions at the index sites. The instantaneous annual mortality rates (Z values) for the ECHG and CC Regions remain above 0.25 ⁻y and according to model predictions, the Adult portion of the population is expected to be declining. However, the density of Adult Northern Abalone at the index sites in the ECHG and CC Regions is increasing. Using the range of growth parameters from the literature, rather than the average, produces a wide range of Z values. It is unclear which (if any) of these pairs of L_∞ and K values reflect the conditions at the index sites. In order to ensure that the population projections in the RPA are accurate and to accurately assess Z values against PDO # 3 “To observe at the index sites (in areas without Sea Otters) that the annual estimated mortality rate for mature (≥ 70 mm SL) Northern Abalone is reduced to < 0.20 [⁻y]…” future work should seek to determine values for L_∞ and K that are reflective of conditions at the index sites in the ECHG and CC Regions.

In contrast to the other survey Regions, Northern Abalone at the index sites on the WCVI appear to be in decline and are moving away from the PDOs. The density of the Juvenile, Adult, and Large size classes has been declining since surveys were initiated in 2003. Declines in density are reflected in the percentage of quadrats with Northern Abalone being reduced by half and a complete absence of Large Northern Abalone in the 2013 survey. Despite these declines, size frequencies show that limited settlement has been occurring, as 1-2 year old Northern Abalone were present in each survey year. Sea Otters were re-introduced to Checleset Bay in the WCVI Region from 1969 to 1972, and within the centre of their range the population is showing minimal growth and is thought to be at or near carrying capacity (Nichol et al. 2015). Sea Otters exert strong predation pressure on intertidal and shallow subtidal communities (Estes 1990; Watson et al. 2011), and Sea Otters are a major predator of Abalone where the where the two co-exist (Fanshawe et al. 2003; Micheli et al. 2008; Lee et al. 2016). It has been suggested based on model predictions that the Northern Abalone population in the WCVI Region is unlikely to reach its recovery objective if Sea Otters and Northern Abalone continue to co-exist (Chades et al. 2012). However, recent work examining the relationship between Sea Otters and Northern Abalone in the WCVI Region (Lee et al. 2016), as well as work in California examining the relationship between Sea Otters and other species of Abalone (Fanshawe et al. 2003; Micheli et al. 2008) suggests that abalone populations can reach a new, alternate stable state and persist at low densities in the face of Sea Otter predation. Though, a longer time series is required to determine if the Northern Abalone population in the WCVI Region will reach an alternate stable state or continue to decline. As new information becomes available, it may be necessary to re-evaluate PDO # 2 that “the mean total density estimates for the West Coast of Vancouver Island do not decline below the level observed in 2003 (0.09 Northern Abalone per m^2)”, since it is unclear if this PDO reflected an alternate stable state with Sea Otter and Northern Abalone co-existence or if it is even attainable in the face of Sea Otter predation.

The Population and Distribution Objectives outlined in the Recovery Strategy and the Action Plan were initially developed over 10 years ago using the best available knowledge. At the time, it was recommended that the objectives be re-assessed and revised when additional information became available. Based on our improved knowledge of the Northern Abalone population in BC, a re-evaluation of these objectives to determine their applicability is recommended.

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Table 1. Summary of observed density data for the entire West Coast Haida Gwaii Region from Northern Abalone index site surveys in 2008 and 2013. Values are mean density (individuals m^{-2}) ± SE for the size classes: 'All', 'Juvenile' (< 70 mm SL), 'Adult' (≥ 70 mm SL), and 'Large' (≥ 100 mm SL). Area is used as the sampling unit for standard error calculations.

		2008		**2013**	
Size	**# Areas**	**Mean**	**SE**	**Mean**	**SE**
All	3	0.814	0.084	1.571	0.468
Juvenile	3	0.751	0.080	1.255	0.584
Adult	3	0.062	0.006	0.316	0.139
Large	3	0.000	0.000	0.018	0.010

Table 2. Observed density data by size category and Area for the West Coast Haida Gwaii Region from Northern Abalone index site surveys in 2008 and 2013. Values are mean density (individuals m^{-2}) ± SE for the size classes: 'All', 'Juvenile' (< 70 mm SL), 'Adult' (≥ 70 mm SL), and 'Large' (≥ 100 mm SL). Values shown in bold are the totals for the entire West Coast Haida Gwaii Region. Site is used as the sampling unit for standard error calculations.

	2008			2013		
Area	**# Sites**	**Mean**	**SE**	**# Sites**	**Mean**	**SE**
All	**37**	**0.838**	**0.144**	**47**	**1.609**	**0.207**
Hippa Island	11	0.670	0.223	13	1.125	0.242
Englefield Bay	17	0.960	0.245	17	2.507	0.430
Gowgaia Bay	9	0.812	0.270	17	1.081	0.206
Juvenile	**37**	**0.776**	**0.140**	**47**	**1.289**	**0.210**
Hippa Island	11	0.608	0.225	13	0.856	0.191
Englefield Bay	17	0.886	0.239	17	2.404	0.432
Gowgaia Bay	9	0.760	0.248	17	0.504	0.127
Adult	**37**	**0.070**	**0.021**	**47**	**0.320**	**0.067**
Hippa Island	11	0.063	0.039	13	0.269	0.118
Englefield Bay	17	0.073	0.036	17	0.103	0.033
Gowgaia Bay	9	0.052	0.023	17	0.577	0.140
Large	**37**	**0.000**	**0.000**	**47**	**0.019**	**0.010**
Hippa Island	11	0.000	0.000	13	0.014	0.014
Englefield Bay	17	0.000	0.000	17	0.004	0.004
Gowgaia Bay	9	0.000	0.000	17	0.037	0.024

Table 3. Percentage of quadrats with Northern Abalone observed during index site surveys on the West Coast of Haida Gwaii in 2008 and 2013. Values are the mean percentage of quadrats with Abalone ± SE. Site is used as the sampling unit for standard error calculations.

	2008			2013		
Area	**# Sites**	**Mean**	**SE**	**# Sites**	**Mean**	**SE**
All Areas	**37**	**32.8**	**4.2**	**47**	**53.3**	**3.9**
Hippa Island	11	32.4	7.7	13	48.1	7.7
Englefield Bay	17	34.9	6.5	17	64.0	5.7
Gowgaia Bay	9	29.3	8.6	17	46.7	6.3

Table 4. Percentage of index sites with at least one Northern Abalone ≥ 100 mm shell length for index site surveys on the West Coast of Haida Gwaii in 2008 and 2013. Values are mean percentage of sites with ≥ 100 mm Abalone ± SE. Area is used as the sampling unit for standard error calculations.

	% Sites		
Year	**# Areas**	**Mean**	**SE**
2008	3	0.0	0.0
2013	3	10.4	3.7

Table 5. Descriptive statistics for Northern Abalone measured during index site surveys on the West Coast of Haida Gwaii in 2008 and 2013.

Area	Count	Shell Length (mm)				
		Mean	**SE**	**Max**	**Min**	**Median**
2008	**490**	**43.8**	**0.9**	**96**	**3**	**47**
Hippa Island	118	46.5	1.7	94	3	47.5
Englefield Bay	260	39.7	1.4	96	3	43.5
Gowgaia Bay	112	50.7	1.3	91	19	51
2013	**1210**	**40.2**	**0.8**	**139**	**1**	**35**
Hippa Island	234	51.8	1.5	107	3	53
Englefield Bay	682	25.3	0.8	139	1	17
Gowgaia Bay	294	65.7	1.3	115	10	71

Table 6. Summary of density data for the East Coast Haida Gwaii Region from Northern Abalone index site surveys, 2002-2012. Values are mean density (individuals m^{-2}) ± SE for the size classes: 'All' (≥ 20 mm SL), 'Juvenile' (≥ 20 mm and < 70 mm SL), 'Adult' (≥ 70 mm SL), and 'Large' (≥ 100 mm). Area is used as the sampling unit for standard error calculations.

	#	2002		2007		2012	
Size	**Areas**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
All	8	0.305	0.094	0.395	0.076	0.796	0.134
Juvenile	8	0.158	0.040	0.241	0.061	0.442	0.103
Adult	8	0.147	0.059	0.154	0.084	0.353	0.084
Large	8	0.038	0.014	0.026	0.008	0.051	0.014

Table 7. Density data by size category and area for East Coast Haida Gwaii Region from Northern Abalone index site surveys, 2002-2012. Values are mean density (individuals m^{-2}) ± SE for the size classes: 'All' (≥ 20 mm SL), 'Juvenile' (≥ 20 mm and < 70 mm SL), 'Adult' (≥ 70 mm SL), and 'Large' (≥ 100 mm). Values shown in bold are the totals for the entire Central Coast region. Site is used as the sampling unit for standard error calculations.

	2002			**2007**			**2012**		
Area	**# Sites**	**Mean**	**SE**	**# Sites**	**Mean**	**SE**	**# Sites**	**Mean**	**SE**
All	**67**	**0.327**	**0.054**	**81**	**0.414**	**0.051**	**83**	**0.836**	**0.090**
Cumshewa Inlet	3	0.000	0.000	8	0.000	0.000	8	0.070	0.049
Selwyn Inlet	6	0.042	0.021	8	0.273	0.051	8	0.695	0.207
Tanu Island	8	0.336	0.099	8	0.570	0.200	8	0.547	0.100
Upper Juan Perez	12	0.339	0.117	14	0.540	0.173	14	1.018	0.177
Lower Juan Perez	8	0.203	0.066	10	0.675	0.166	10	0.969	0.321
Skincuttle Inlet	13	0.163	0.052	13	0.490	0.075	14	0.848	0.207
Carpenter Bay	10	0.569	0.209	11	0.307	0.118	11	0.858	0.189
Kunghit Island	7	0.786	0.238	9	0.306	0.111	10	1.363	0.422
Juvenile	**67**	**0.172**	**0.035**	**81**	**0.261**	**0.038**	**83**	**0.468**	**0.064**
Cumshewa Inlet	3	0.000	0.000	8	0.000	0.000	8	0.016	0.016
Selwyn Inlet	6	0.031	0.021	8	0.203	0.051	8	0.453	0.122
Tanu Island	8	0.195	0.070	8	0.117	0.046	8	0.148	0.046
Upper Juan Perez	12	0.193	0.101	14	0.357	0.124	14	0.696	0.161
Lower Juan Perez	8	0.172	0.063	10	0.569	0.152	10	0.906	0.314
Skincuttle Inlet	13	0.077	0.023	13	0.303	0.063	14	0.379	0.096
Carpenter Bay	10	0.306	0.173	11	0.250	0.111	11	0.335	0.092
Kunghit Island	7	0.286	0.069	9	0.132	0.054	10	0.606	0.246
Adult	**67**	**0.156**	**0.031**	**81**	**0.154**	**0.029**	**83**	**0.368**	**0.050**
Cumshewa Inlet	3	0.000	0.000	8	0.000	0.000	8	0.055	0.046
Selwyn Inlet	6	0.010	0.010	8	0.070	0.025	8	0.242	0.115
Tanu Island	8	0.141	0.054	8	0.453	0.166	8	0.398	0.092
Upper Juan Perez	12	0.146	0.042	14	0.183	0.089	14	0.321	0.057
Lower Juan Perez	8	0.031	0.017	10	0.106	0.042	10	0.063	0.023
Skincuttle Inlet	13	0.087	0.037	13	0.188	0.057	14	0.469	0.166
Carpenter Bay	10	0.263	0.090	11	0.057	0.026	11	0.523	0.153
Kunghit Island	7	0.500	0.200	9	0.174	0.087	10	0.756	0.203
Large	**67**	**0.043**	**0.011**	**81**	**0.027**	**0.009**	**83**	**0.054**	**0.014**
Cumshewa Inlet	3	0.000	0.000	8	0.000	0.000	8	0.008	0.008
Selwyn Inlet	6	0.000	0.000	8	0.000	0.000	8	0.008	0.008
Tanu Island	8	0.016	0.016	8	0.063	0.054	8	0.102	0.037
Upper Juan Perez	12	0.068	0.031	14	0.031	0.018	14	0.049	0.022
Lower Juan Perez	8	0.008	0.008	10	0.038	0.038	10	0.000	0.000
Skincuttle Inlet	13	0.039	0.023	13	0.043	0.025	14	0.089	0.056
Carpenter Bay	10	0.056	0.040	11	0.006	0.006	11	0.068	0.056
Kunghit Island	7	0.116	0.044	9	0.028	0.015	10	0.081	0.025

Table 8. Percentage of index sites with at least one Northern Abalone ≥ 100 mm shell length for index site surveys on the East Coast of Haida Gwaii, 2002-2012. Values are mean percentage of sites with ≥ 100 mm Abalone ± SE. Area is used as the sampling unit for standard error calculations.

	% of Sites		
Year	**# Areas**	**Mean**	**SE**
2002	8	23.4	9.8
2007	8	17.1	4.9
2012	8	30.2	8.7

Table 9. Percentage of quadrats with Northern Abalone observed during index site surveys on the East Coast of Haida Gwaii, 2002-2012. Values are the mean percentage of quadrats with Abalone ± SE. Site is used as the sampling unit for standard error calculations.

	2002			2007			2012		
Area	**# Sites**	**Mean**	**SE**	**# Sites**	**Mean**	**SE**	**# Sites**	**Mean**	**SE**
All Areas	**67**	**19.3**	**2.4**	**81**	**23.1**	**2.3**	**83**	**40.7**	**2.9**
Cumshewa Inlet	3	0.0	0.0	8	0.0	0.0	8	6.3	4.3
Selwyn Inlet	6	4.2	2.1	8	18.8	3.3	8	41.4	7.6
Tanu Island	8	21.9	5.5	8	32.8	11.6	8	30.5	6.3
Upper Juan Perez	12	22.4	5.4	14	27.2	6.1	14	48.7	5.1
Lower Juan Perez	8	14.8	4.9	10	39.4	5.7	10	51.9	7.6
Skincuttle Inlet	13	12.5	3.7	13	26.9	3.9	14	46.4	8.7
Carpenter Bay	10	27.5	8.3	11	16.5	4.3	11	39.2	7.2
Kunghit Island	7	38.4	7.9	9	17.4	5.7	10	47.5	9.4

Table 10. Descriptive statistics for all Northern Abalone measured during index site surveys on the East Coast of Haida Gwaii, 2002-2012. Data are hedged at a minimum shell length of 20 mm due to the cryptic nature and difficultly in detecting abalone smaller than this size.

		Shell Length (mm)				
Area	**Count**	**Mean**	**SE**	**Max**	**Min**	**Median**
2002	**351**	**68.6**	**1.3**	**135**	**20**	**68**
Cumshewa Inlet	0					
Selwyn Inlet	4	62.8	4.4	70	51	65
Tanu Island	43	65.6	3.1	117	25	65
Upper Juan Perez	65	68.2	3.8	128	21	68
Lower Juan Perez	26	51.7	4.2	100	23	47.5
Skincuttle Inlet	34	71.1	4.4	123	26	71
Carpenter Bay	91	67.2	2.6	121	21	67
Kunghit Island	88	76.3	2.3	135	20	80
2007	**537**	**63.5**	**0.9**	**132**	**21**	**61**
Cumshewa Inlet	0					
Selwyn Inlet	35	59.0	2.5	86	24	57
Tanu Island	73	79.0	2.1	118	25	81
Upper Juan Perez	121	62.9	1.8	118	23	59
Lower Juan Perez	108	52.3	2.1	122	21	47
Skincuttle Inlet	102	67.1	2.1	132	23	64.5
Carpenter Bay	54	57.0	2.3	114	25	55
Kunghit Island	44	70.0	3.2	115	30	71
2012	**1110**	**65.0**	**0.7**	**136**	**20**	**65**
Cumshewa Inlet	9	79.4	11.1	126	25	89
Selwyn Inlet	89	59.7	2.0	100	20	64
Tanu Island	70	82.0	2.5	136	20	80
Upper Juan Perez	228	60.0	1.4	121	20	55
Lower Juan Perez	155	47.6	1.2	94	20	47
Skincuttle Inlet	190	68.5	1.8	120	20	72
Carpenter Bay	151	71.9	1.7	115	21	75
Kunghit Island	218	71.0	1.3	115	25	71

Table 11. Instantaneous annual mortality rate estimates (*Z*) for the East Coast Haida Gwaii Region calculated using the range of literature values for asymptotic length (L_∞) and growth rate (*K*). Values in bold were calculated using the mean of the literature values for L_∞ and *K* as in Zhang et al. (2007).

	Growth Parameters		Estimated Mortality	
Source	L_∞	*K*	**Mean**	**SE**
Zhang et al. 2007	**112.6**	**0.265**	**0.252**	**0.016**
Schnute and Fournier 1980	141.8	0.182	0.251	0.015
Schnute and Fournier 1980	120.1	0.243	0.257	0.016
Schnute and Fournier 1980	125	0.234	0.261	0.017
Schnute and Fournier 1980	132.8	0.216	0.262	0.017
Breen 1986	123.7	0.317	0.237	0.020
Breen 1986	137.3	0.204	0.262	0.017
Breen 1986	129.8	0.230	0.265	0.018
Breen 1986	122.6	0.158	0.180	0.010
Breen 1986	114.2	0.351	0.272	0.019
Breen 1986	100.6	0.505	0.273	0.019
Breen 1986	95.2	0.195	0.151	0.010
Breen 1986	113.8	0.241	0.236	0.013

Table 12. Summary of density data for the entire Central Coast Region from Northern Abalone index site surveys 2001-2016. Values are mean density (individuals m^{-2}) ± SE for the size classes: 'All' (≥ 20 mm SL), 'Juvenile' (≥ 20 mm and < 70 mm SL), 'Adult' (≥ 70 mm SL), and 'Large' (≥ 100 mm). Area is used as the sampling unit for standard error calculations.

	#	2001		2006		2011		2016	
Size	**Areas**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
All	9	0.272	0.043	0.414	0.079	0.896	0.128	1.930	0.244
Juvenile	9	0.099	0.012	0.167	0.027	0.461	0.066	1.327	0.210
Adult	9	0.173	0.036	0.247	0.058	0.436	0.104	0.604	0.157
Large	9	0.043	0.015	0.023	0.008	0.073	0.026	0.085	0.029

Table 13. Density data by size category and Area for the Central Coast Region from Northern Abalone index site surveys, 2001-2016. Values are mean density (individuals m^{-2}) ± SE for the size classes: 'All' (≥ 20 mm SL), 'Juvenile' (≥ 20 mm and < 70 mm SL), 'Adult' (≥ 70 mm SL), and 'Large' (≥ 100 mm). Values shown in bold are the totals for the entire Central Coast Region. Site is used as the sampling unit for standard error calculations.

	2001			2006			2011			2016		
Area	**# Sites**	**Mean**	**SE**	**# Sites**	**Mean**	**SE**	**# Sites**	**Mean**	**SE**	**# Sites**	**Mean**	**SE**
All	**55**	**0.263**	**0.044**	**68**	**0.389**	**0.058**	**76**	**0.881**	**0.090**	**78**	**1.862**	**0.210**
North Banks Is.	4	0.438	0.133	8	0.406	0.274	10	0.700	0.255	10	1.531	0.411
Oswald Bay	3	0.083	0.055	6	0.250	0.130	7	0.714	0.257	6	1.375	0.312
Pemberton Bay	4	0.219	0.097	4	0.891	0.200	4	0.984	0.209	5	3.550	1.194
Lotbiniere Bay	8	0.414	0.140	8	0.289	0.097	9	0.674	0.321	11	1.631	0.589
North Aristazabal Is.	7	0.304	0.120	10	0.400	0.127	10	0.988	0.206	10	1.631	0.411
South Aristazabal Is.	11	0.080	0.019	9	0.230	0.075	12	0.755	0.216	12	2.115	0.705
Stryker Is.	8	0.227	0.128	8	0.210	0.112	8	0.828	0.173	8	1.742	0.917
Simonds Group	6	0.354	0.230	8	0.719	0.261	8	1.852	0.355	8	2.586	0.580
Spider Is.	4	0.328	0.160	7	0.330	0.118	8	0.570	0.156	8	1.211	0.329
Juvenile	**55**	**0.097**	**0.017**	**68**	**0.162**	**0.028**	**76**	**0.457**	**0.051**	**78**	**1.300**	**0.175**
North Banks Is.	4	0.125	0.044	8	0.078	0.053	10	0.294	0.091	10	1.175	0.375
Oswald Bay	3	0.063	0.063	6	0.073	0.034	7	0.179	0.066	6	0.615	0.368
Pemberton Bay	4	0.063	0.036	4	0.313	0.142	4	0.609	0.064	5	2.075	0.609
Lotbiniere Bay	8	0.109	0.069	8	0.102	0.033	9	0.257	0.137	11	0.551	0.184
North Aristazabal Is.	7	0.152	0.044	10	0.194	0.063	10	0.556	0.139	10	0.794	0.196
South Aristazabal Is.	11	0.051	0.014	9	0.154	0.043	12	0.563	0.183	12	1.927	0.690
Stryker Is.	8	0.102	0.058	8	0.162	0.102	8	0.711	0.169	8	1.664	0.905
Simonds Group	6	0.083	0.053	8	0.266	0.161	8	0.664	0.161	8	2.117	0.473
Spider Is.	4	0.141	0.082	7	0.161	0.079	8	0.313	0.098	8	1.023	0.279
Adult	**55**	**0.166**	**0.033**	**68**	**0.227**	**0.041**	**76**	**0.424**	**0.061**	**78**	**0.563**	**0.098**
North Banks Is.	4	0.313	0.088	8	0.328	0.231	10	0.406	0.195	10	0.356	0.092
Oswald Bay	3	0.021	0.021	6	0.177	0.118	7	0.536	0.220	6	0.760	0.127
Pemberton Bay	4	0.156	0.065	4	0.578	0.136	4	0.375	0.147	5	1.475	0.694
Lotbiniere Bay	8	0.305	0.096	8	0.188	0.069	9	0.417	0.203	11	1.080	0.464
North Aristazabal Is.	7	0.152	0.073	10	0.206	0.073	10	0.431	0.106	10	0.838	0.300
South Aristazabal Is.	11	0.028	0.013	9	0.076	0.037	12	0.193	0.062	12	0.188	0.051
Stryker Is.	8	0.125	0.101	8	0.048	0.026	8	0.117	0.038	8	0.078	0.035
Simonds Group	6	0.271	0.187	8	0.453	0.138	8	1.188	0.259	8	0.469	0.154
Spider Is.	4	0.188	0.092	7	0.170	0.098	8	0.258	0.124	8	0.188	0.059
Large	**55**	**0.040**	**0.012**	**68**	**0.022**	**0.009**	**76**	**0.072**	**0.015**	**78**	**0.079**	**0.017**
North Banks Is.	4	0.125	0.036	8	0.070	0.070	10	0.100	0.048	10	0.044	0.021
Oswald Bay	3	0.021	0.021	6	0.052	0.041	7	0.125	0.045	6	0.146	0.110
Pemberton Bay	4	0.000	0.000	4	0.016	0.016	4	0.016	0.016	5	0.200	0.121
Lotbiniere Bay	8	0.086	0.031	8	0.000	0.000	9	0.042	0.018	11	0.227	0.061
North Aristazabal Is.	7	0.009	0.009	10	0.013	0.008	10	0.063	0.030	10	0.081	0.035
South Aristazabal Is.	11	0.000	0.000	9	0.007	0.007	12	0.021	0.012	12	0.010	0.007
Stryker Is.	8	0.023	0.023	8	0.008	0.008	8	0.008	0.008	8	0.000	0.000
Simonds Group	6	0.094	0.082	8	0.016	0.010	8	0.255	0.094	8	0.047	0.016
Spider Is.	4	0.031	0.031	7	0.027	0.019	8	0.023	0.016	8	0.008	0.008

Table 14. Percentage of index sites with at least one Northern Abalone ≥ 100 mm shell length for index site surveys on the Central Coast, 2001-2016. Values are mean percentage of sites with ≥ 100 mm Abalone ± SE. Area is used as the sampling unit for standard error calculations.

		% of Sites	
Year	**# Areas**	**Mean**	**SE**
2001	9	31.2	10.8
2006	9	18.7	3.5
2011	9	40.9	7.2
2016	9	42.5	9.5

Table 15. Percentage of quadrats with Northern Abalone observed during index site surveys on the Central Coast, 2001-2016. Values are the mean percentage of quadrats with Abalone ± SE. Site is used as the sampling unit for standard error calculations.

	2001			**2006**			**2011**			**2016**		
Area	**# Sites**	**Mean**	**SE**	**# Sites**	**Mean**	**SE**	**# Sites**	**Mean**	**SE**	**# Sites**	**Mean**	**SE**
All Areas	**55**	**14.5**	**2.0**	**68**	**21.3**	**2.4**	**76**	**38.7**	**2.7**	**78**	**55.3**	**2.8**
North Banks Is.	4	26.6	7.4	8	14.8	9.1	10	32.5	8.4	10	51.9	9.7
Oswald Bay	3	8.3	5.5	6	13.5	5.5	7	33.9	6.4	6	56.3	5.1
Pemberton Bay	4	15.6	9.7	4	45.3	6.9	4	43.8	5.1	5	66.3	7.3
Lotbiniere Bay	8	21.9	6.5	8	19.5	6.5	9	28.5	9.7	11	49.4	7.3
North Aristazabal Is.	7	16.1	4.1	10	22.5	5.0	10	43.1	5.1	10	51.3	8.7
South Aristazabal Is.	11	6.8	1.6	9	16.8	4.9	12	35.4	5.7	12	54.7	6.9
Stryker Is.	8	7.8	4.2	8	12.8	6.1	8	45.3	8.2	8	47.7	9.7
Simonds Group	6	14.6	7.0	8	35.2	8.4	8	58.6	10.6	8	78.1	7.3
Spider Is.	4	23.4	11.8	7	21.4	6.9	8	32.0	6.9	8	50.8	9.6

Table 16. Descriptive statistics for all Northern Abalone measured during index site surveys on the Central Coast 2001-2016. Data are hedged at a minimum shell length of 20 mm due to the cryptic nature and difficultly in detecting Abalone smaller than this size.

		Shell Length (mm)				
Area	**Count**	**Mean**	**SE**	**Max**	**Min**	**Median**
2001	**229**	**77.8**	**1.4**	**122**	**29**	**81**
North Banks Is.	28	86.0	3.5	118	56	85
Oswald Bay	4	72.0	9.9	101	56	66
Pemberton Bay	14	76.5	4.4	99	48	80
Lotbiniere Bay	53	82.2	2.6	122	40	86
North Aristazabal Is.	34	70.1	3.5	112	38	68
South Aristazabal Is.	14	60.4	5.1	89	29	53
Stryker Is.	27	75.3	4.1	115	30	76
Simonds Group	34	83.8	3.4	118	32	88
Spider Is.	21	75.4	4.7	122	34	80
2006	**422**	**70.9**	**1.0**	**122**	**20**	**74**
North Banks Is.	52	83.0	2.6	116	38	85
Oswald Bay	24	80.4	4.8	122	28	87
Pemberton Bay	57	72.6	2.0	112	36	76
Lotbiniere Bay	37	72.1	3.1	98	25	79
North Aristazabal Is.	64	66.7	2.5	103	20	71
South Aristazabal Is.	33	60.7	3.6	105	28	59
Stryker Is.	26	62.8	3.2	104	35	62
Simonds Group	92	71.9	1.9	110	28	74
Spider Is.	37	63.6	3.8	108	24	70
2011	**1049**	**68.1**	**0.7**	**124**	**20**	**68**
North Banks Is.	112	73.8	2.3	124	22	76
Oswald Bay	80	81.4	2.3	120	20	87
Pemberton Bay	63	66.0	2.2	102	29	65
Lotbiniere Bay	97	77.0	1.5	106	38	77
North Aristazabal Is.	158	64.0	1.8	119	21	66
South Aristazabal Is.	145	57.7	1.6	106	21	56
Stryker Is.	106	49.2	1.8	100	20	48
Simonds Group	215	75.4	1.5	124	20	76
Spider Is.	73	70.0	2.5	113	22	68
2016	**2689**	**54.2**	**0.5**	**132**	**20**	**51**
North Banks Is.	245	49.6	1.6	115	20	44
Oswald Bay	132	69.2	2.1	111	24	72
Pemberton Bay	284	66.9	1.1	120	20	66
Lotbiniere Bay	287	76.1	1.4	132	20	79
North Aristazabal Is.	261	67.4	1.4	112	20	70
South Aristazabal Is.	406	42.4	0.9	118	20	38
Stryker Is.	446	41.3	0.7	86	20	40
Simonds Group	331	49.1	1.1	111	20	45
Spider Is.	297	47.8	1.1	105	20	45

Table 17. Instantaneous annual mortality rate estimates (*Z*) for the Central Coast Region calculated using the range of literature values for asymptotic length (L_∞) and growth rate (*K*). Values in bold were calculated using the mean of the literature values for L_∞ and *K* as in Zhang et al. (2007).

	Growth Parameters		Estimated Mortality	
Source	L_∞	*K*	**Mean**	**SE**
Zhang et al. 2007	**112.6**	**0.265**	**0.295**	**0.023**
Schnute and Fournier 1980	141.8	0.182	0.294	0.023
Schnute and Fournier 1980	120.1	0.243	0.298	0.025
Schnute and Fournier 1980	125	0.234	0.301	0.024
Schnute and Fournier 1980	132.8	0.216	0.302	0.024
Breen 1986	123.7	0.317	0.310	0.027
Breen 1986	137.3	0.204	0.303	0.025
Breen 1986	129.8	0.230	0.303	0.025
Breen 1986	122.6	0.158	0.203	0.016
Breen 1986	114.2	0.351	0.309	0.026
Breen 1986	100.6	0.505	0.310	0.026
Breen 1986	95.2	0.195	0.118	0.014
Breen 1986	113.8	0.241	0.283	0.021

Table 18. Density of Northern Abalone by size category and Area for index site surveys conducted in the Gordon Channel (2004 to 2014) and North Queen Charlotte Strait (2009 and 2014) Areas of the Queen Charlotte Strait Region. Values are mean density (individuals m^{-2}) ± SE for the size classes: ‘All’, ‘Juvenile’ (< 70 mm SL), ‘Adult’ (≥ 70 mm SL), and ‘Large’ (≥ 100 mm). Site is used as the sampling unit for standard error calculations.

	2004			2009			2014		
Area	**# Sites**	**Mean**	**SE**	**# Sites**	**Mean**	**SE**	**# Sites**	**Mean**	**SE**
Gordon Channel									
All	19	0.042	0.020	17	0.164	0.061	17	0.147	0.046
Juvenile	19	0.019	0.016	17	0.057	0.023	17	0.066	0.022
Adult	19	0.039	0.019	17	0.110	0.047	17	0.081	0.030
Large	19	0.003	0.003	17	0.039	0.017	17	0.029	0.015
North Queen Charlotte Strait									
All				15	0.063	0.022	14	0.051	0.026
Juvenile				15	0.021	0.017	14	0.015	0.008
Adult				15	0.042	0.018	14	0.036	0.019
Large				15	0.008	0.006	14	0.025	0.013

Table 19. Percentage of Sites with at least one Northern Abalone ≥ 100 mm shell length for index site surveys in Queen Charlotte Strait, 2004-2014.

Year	# Sites	Sites with ≥ 100 mm Abalone	
		Count	%
Gordon Channel			
2004	19	1	5.3
2009	17	5	29.4
2014	17	5	29.4
North Queen Charlotte Strait			
2009	15	2	13.3
2014	14	4	28.6

Table 20. Percentage of quadrats with Northern Abalone observed during index site surveys in Queen Charlotte Strait (2004-2014). Values are the mean percentage of quadrats with Abalone ± SE. Site is used as the sampling unit for standard error calculations.

		Quadrats with Abalone (%)	
Year	**# Sites**	**Mean**	**SE**
Gordon Channel			
2004	19	3.2	1.5
2009	17	10.4	3.7
2014	17	11.3	2.8
North Queen Charlotte Strait			
2009	15	4.6	1.6
2014	14	4.5	2.1

Table 21. Descriptive statistics for all Northern Abalone measured during index site surveys in Queen Charlotte Strait (2004-2014).

		Shell Length (mm)				
Year	**Count**	**Mean**	**SE**	**Max**	**Min**	**Median**
Gordon Channel						
2004	13	77.7	4.9	114	56	80
2009	39	79.8	2.9	107	47	81
2014	37	70.2	4.9	125	2	71
North Queen Charlotte Strait						
2009	15	76.1	5.6	106	34	83
2014	10	91.5	9.1	125	46	98

Table 22. Summary of density data at repeated sites in the West Coast Vancouver Island Region from Northern Abalone index site surveys, 2003-2013. See Appendix 1 for a list of repeated sites. Values are mean density (individuals m^{-2}) ± SE for the size classes: 'All', 'Juvenile' (< 70 mm SL), 'Adult' (≥ 70 mm SL), and 'Large' (≥ 100 mm). Site is used as the sampling unit for standard error calculations.

		2003		2008		2013	
Size	**# Sites**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
All	16	0.180	0.071	0.133	0.036	0.063	0.019
Juvenile	16	0.105	0.062	0.082	0.028	0.055	0.016
Adult	16	0.074	0.024	0.051	0.016	0.008	0.005
Large	16	0.008	0.008	0.004	0.004	0.000	0.000

Table 23. Percentage of quadrats with Northern Abalone observed at repeated sites during index site surveys on the West Coast of Vancouver Island. See Appendix 1 for a list of repeated sites. Values are the mean percentage of quadrats with Abalone ± SE. Site is used as the sampling unit for standard error calculations.

		Quadrats with Abalone (%)	
Year	**# Sites**	**Mean**	**SE**
2003	16	13.3	4.1
2008	16	11.3	2.7
2013	16	5.9	1.8

Table 24. Descriptive statistics for all Northern Abalone measured at repeated sites during index site surveys on the West Coast of Vancouver Island from 2003-2013. See Appendix 1 for a list of Sites that were repeated in each year.

		Shell Length (mm)				
Year	**Count**	**Mean**	**SE**	**Max**	**Min**	**Median**
2003	46	60.0	3.6	101	22	64
2008	34	60.5	4.1	105	24	58
2013	16	48.1	4.0	76	21	48

Table 25. Density data by size category and Area for the West Coast Vancouver Island Region from Northern Abalone index site surveys 2003-2013. Values are mean density (individuals m^{-2}) ± SE for the size classes: 'All', 'Juvenile' (< 70 mm SL), 'Adult' (≥ 70 mm SL), and 'Large' (≥ 100 mm). Site is used as the sampling unit for standard error calculations.

	2003			2008			2013		
Area	**# Sites**	**Mean**	**SE**	**# Sites**	**Mean**	**SE**	**# Sites**	**Mean**	**SE**
All									
Quatsino Sound	13	0.207	0.085	11	0.159	0.039	18	0.059	0.017
Brooks Bay	5	0.038	0.038	12	0.047	0.032	16	0.082	0.023
Checleset Bay							18	0.090	0.022
Kyuquot Sound							10	0.144	0.063
Juvenile									
Quatsino Sound	13	0.120	0.076	11	0.102	0.037	18	0.045	0.014
Brooks Bay	5	0.025	0.025	12	0.031	0.018	16	0.051	0.018
Checleset Bay							18	0.073	0.018
Kyuquot Sound							10	0.125	0.053
Adult									
Quatsino Sound	13	0.087	0.029	11	0.057	0.018	18	0.014	0.006
Brooks Bay	5	0.013	0.013	12	0.016	0.016	16	0.031	0.016
Checleset Bay							18	0.017	0.010
Kyuquot Sound							10	0.019	0.019
Large									
Quatsino Sound	13	0.010	0.010	11	0.006	0.006	18	0.000	0.000
Brooks Bay	5	0.000	0.000	12	0.000	0.000	16	0.000	0.000
Checleset Bay							18	0.000	0.000
Kyuquot Sound							10	0.000	0.000

Table 26. Percentage of quadrats with Northern Abalone observed during index site surveys on the West Coast of Vancouver Island, 2003-2013. Values are the mean percentage of quadrats with Abalone ± SE. Individual index site is used as the sampling unit for standard error calculations.

	2003			2008			2013		
Area	**# Sites**	**Mean**	**SE**	**# Sites**	**Mean**	**SE**	**# Sites**	**Mean**	**SE**
Quatsino Sound	13	14.9	4.8	11	14.2	2.93	18	5.9	1.7
Brooks Bay	5	3.8	3.8	12	4.2	2.35	16	8.2	2.3
Checleset Bay							18	9.7	2.2
Kyuquot Sound							10	13.8	4.4

Table 27. Descriptive statistics for Northern Abalone measured at all index sites surveyed on the West Coast of Vancouver Island, 2003-2013.

		Shell Length (mm)				
Year	**Count**	**Mean**	**SE**	**Max**	**Min**	**Median**
2003						
Quatsino Sound	43	60.3	3.8	101	22	64
Brooks Bay	3	56.3	17.4	91	36	42
2008						
Quatsino Sound	28	60.7	4.7	105	24	56
Brooks Bay	9	55.4	6.9	91	36	42
2013						
Quatsino Sound	17	53.5	4.4	88	21	51
Brooks Bay	21	62.2	3.8	89	25	62
Checleset Bay	26	48.3	3.3	80	23	45.5
Kyuquot Sound	23	52.3	3.3	79	21	57

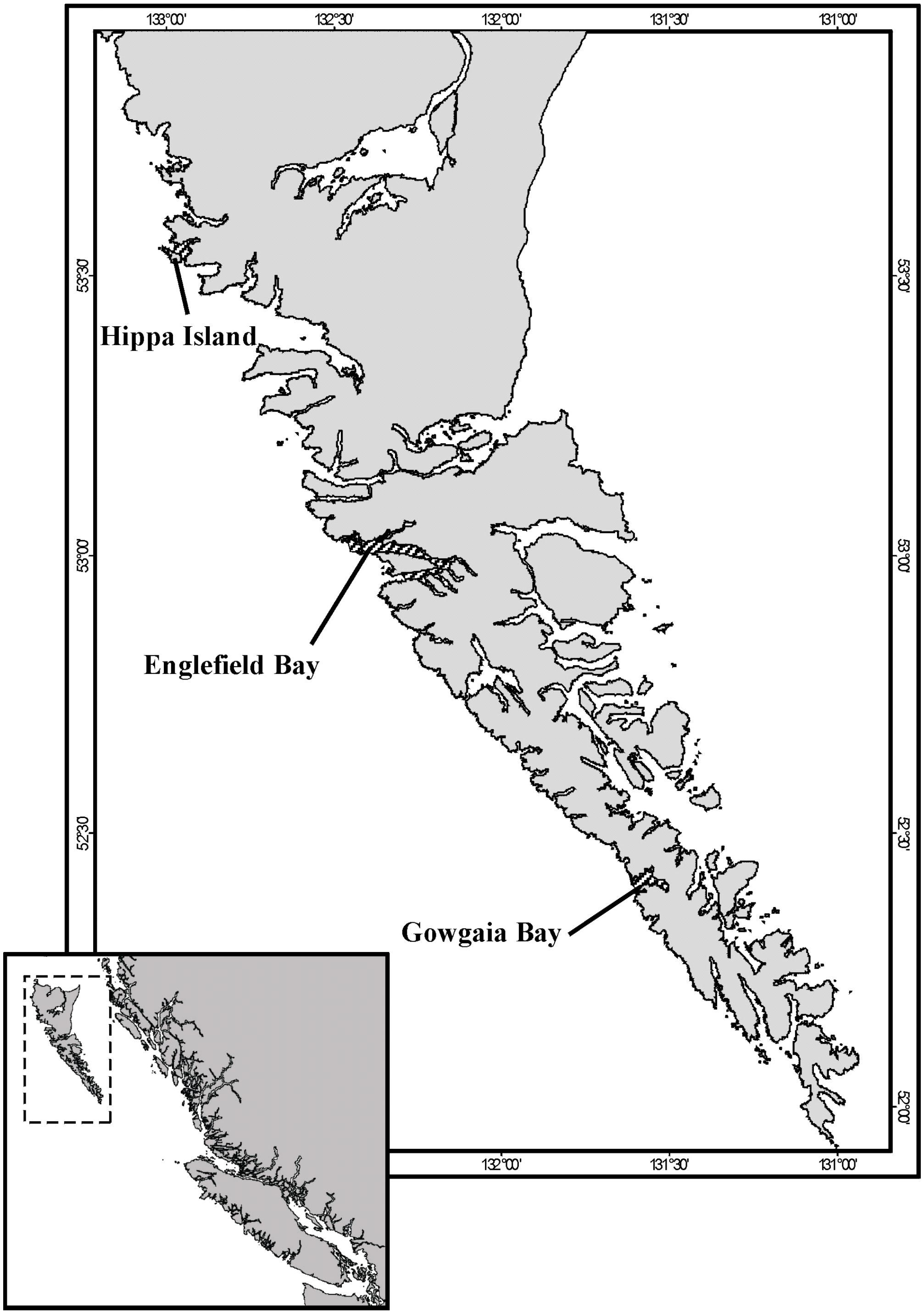


Figure 1. Map showing the Areas containing Northern Abalone (*Haliotis kamtschatkana*) index sites for the West Coast Haida Gwaii Region.

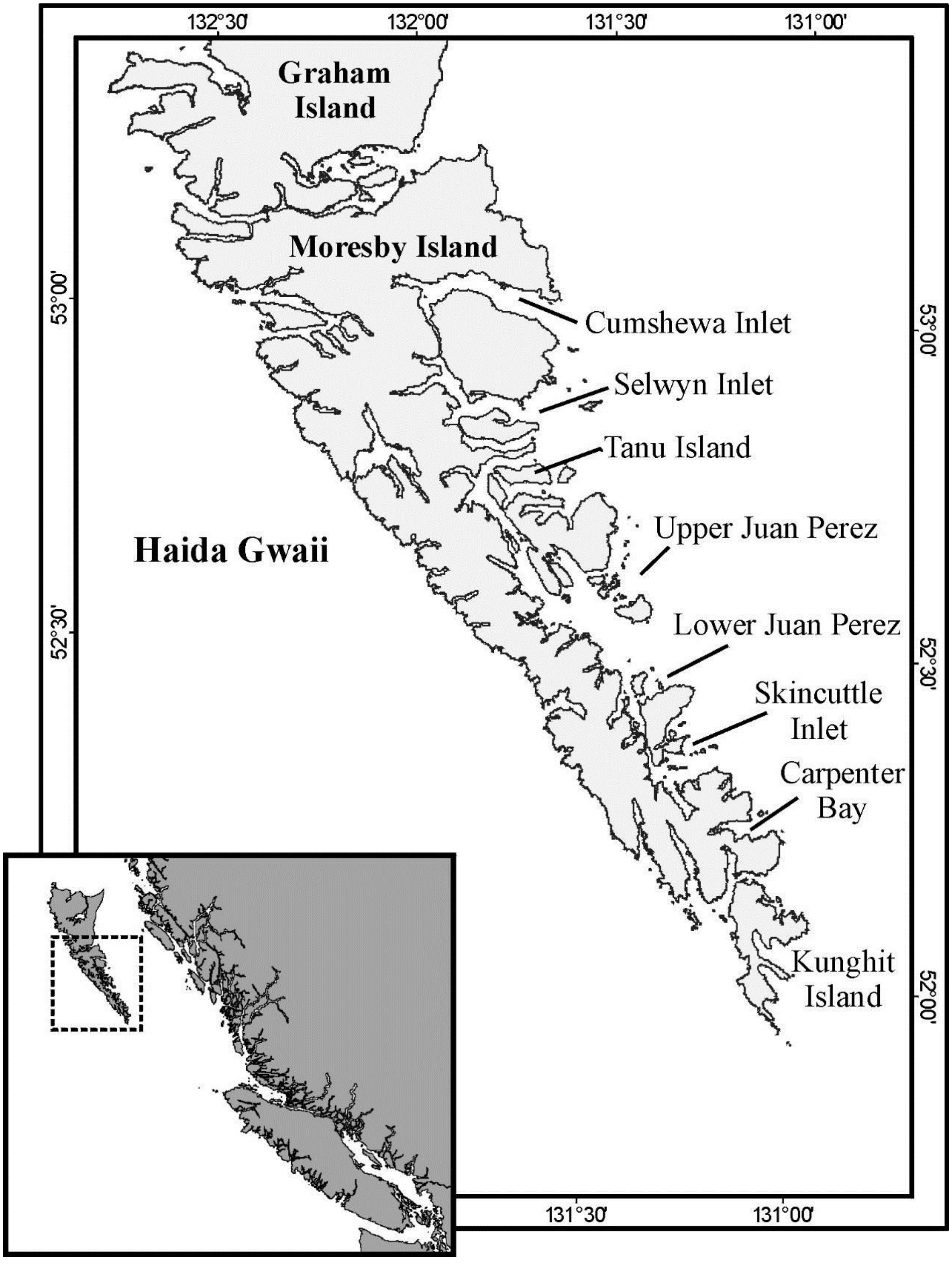


Figure 2. Map showing the Areas containing Northern Abalone (*Haliotis kamtschatkana*) index sites for the East Coast Haida Gwaii Region.

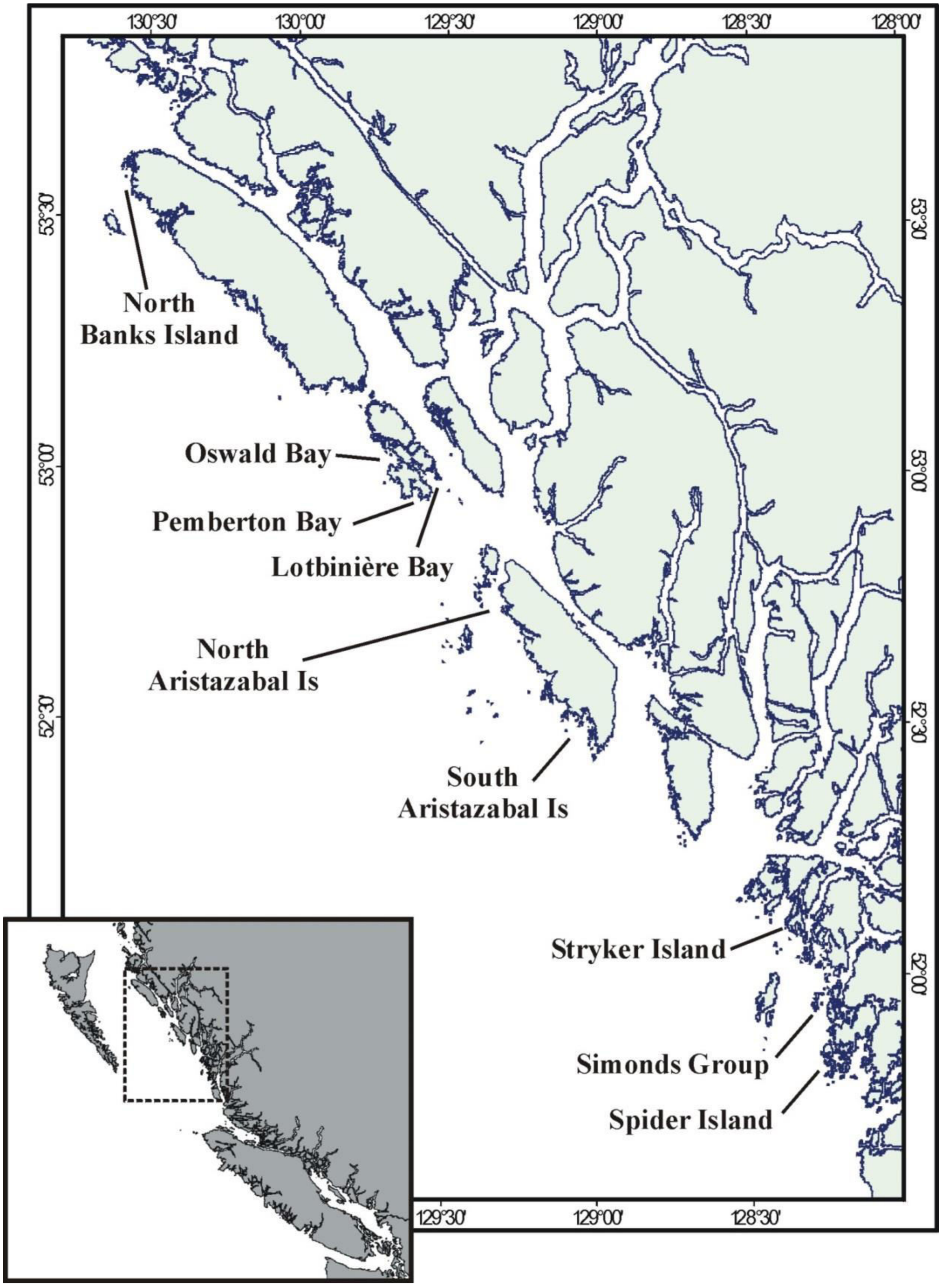


Figure 3. Map showing the Areas containing Northern Abalone (*Haliotis kamtschatkana*) index sites for the Central Coast Region.

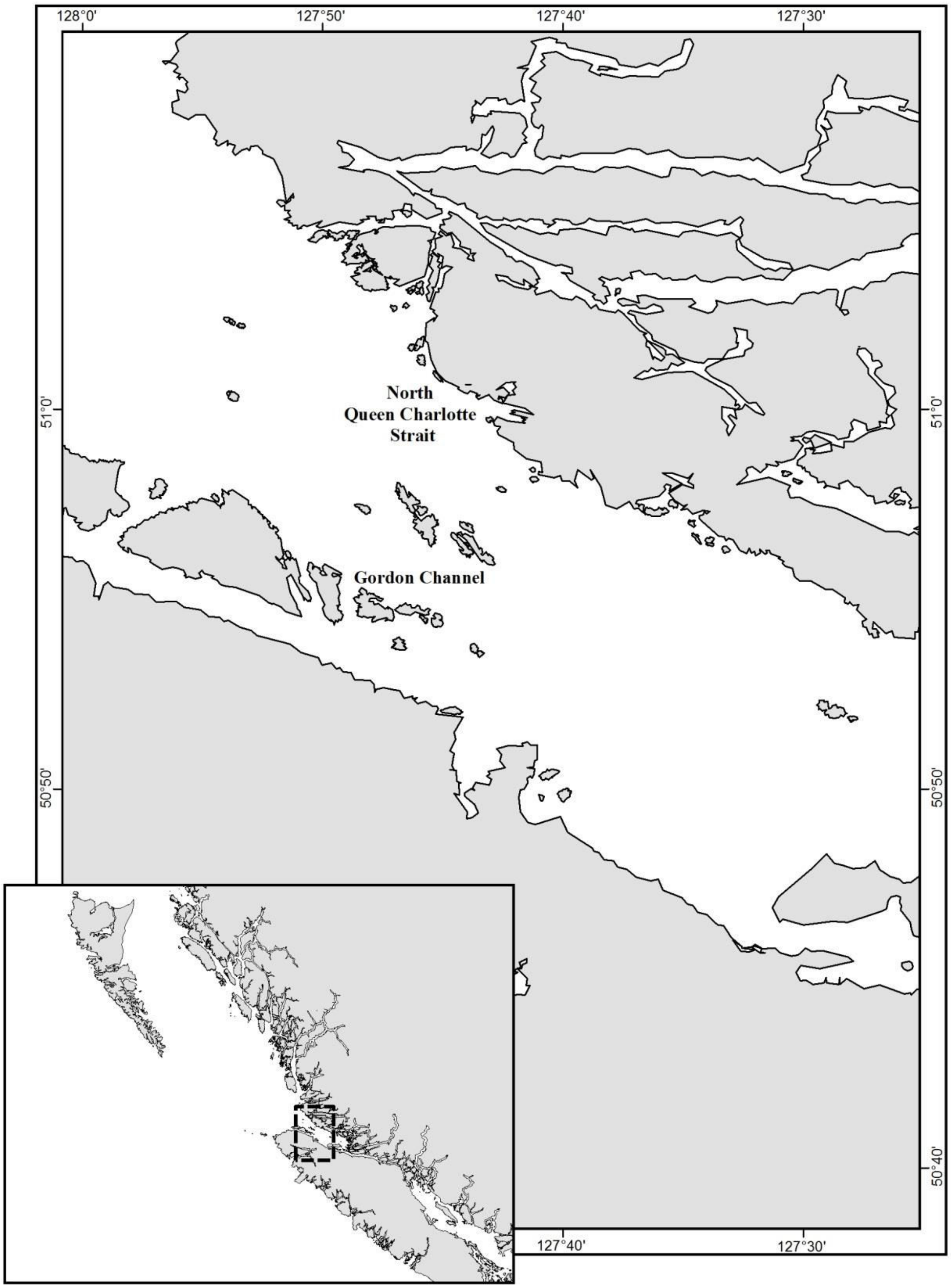


Figure 4. Map showing the Areas containing Northern Abalone (*Haliotis kamtschatkana*) index sites for the Queen Charlotte Strait Region.

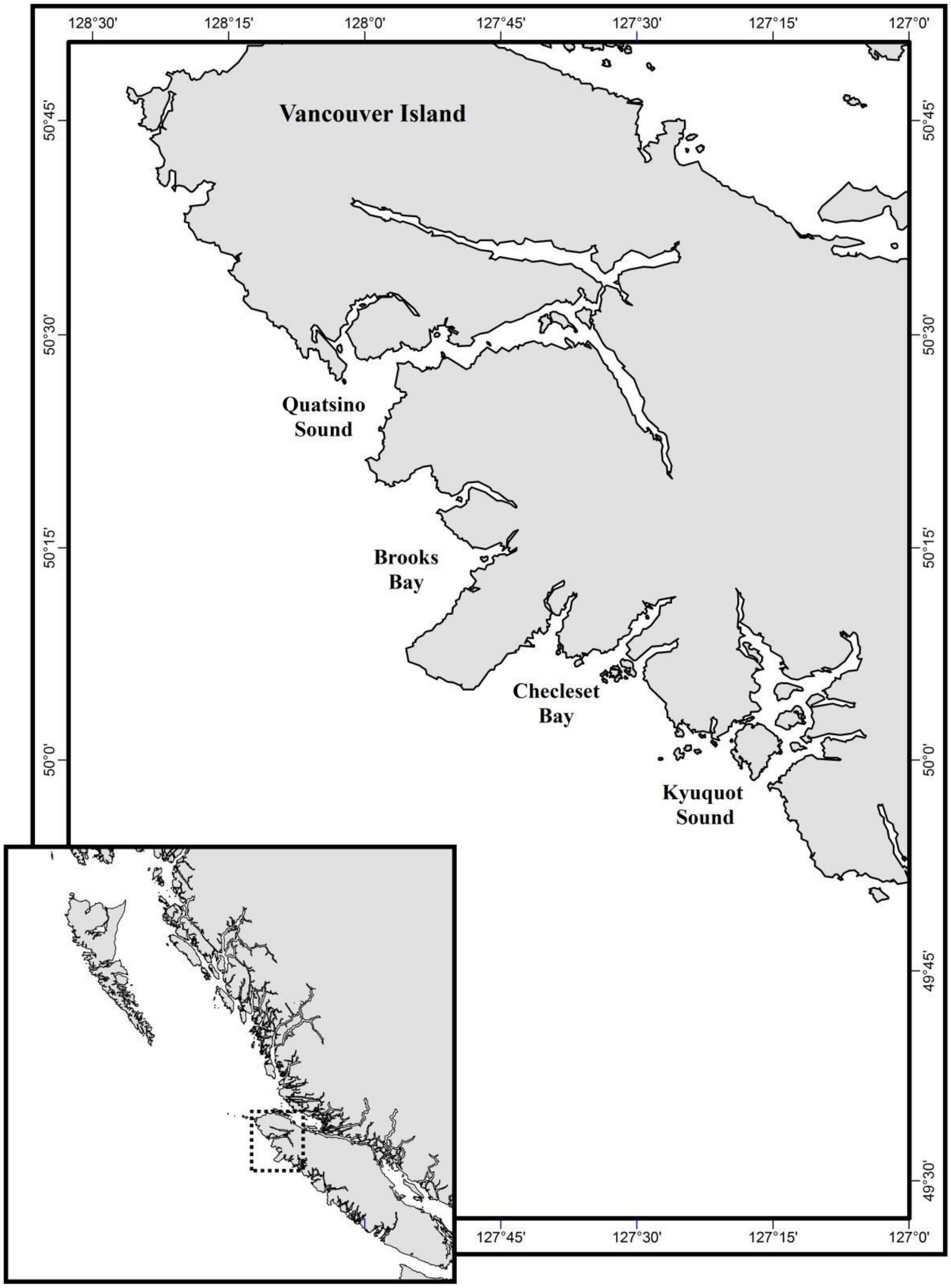


Figure 5. Map showing the Areas containing Northern Abalone (*Haliotis kamtschatkana*) index sites for the West Coast Vancouver Island Region.

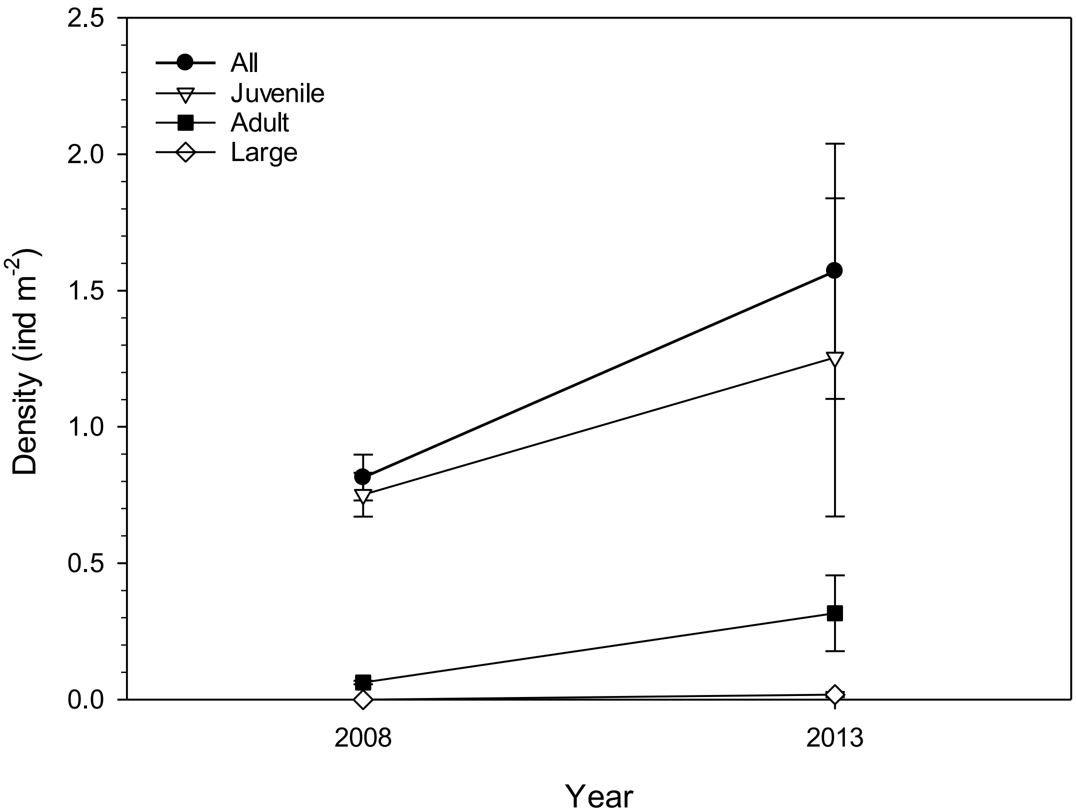


Figure 6. Summary of observed density data for the entire West Coast Haida Gwaii Region from Northern Abalone index site surveys in 2008 and 2013. Values are mean density (individuals m^{-2}) ± SE for the size classes: 'All', 'Juvenile' (< 70 mm SL), 'Adult' (≥ 70 mm SL), and 'Large' (≥ 100 mm). Area is used as the sampling unit for standard error calculations**.**

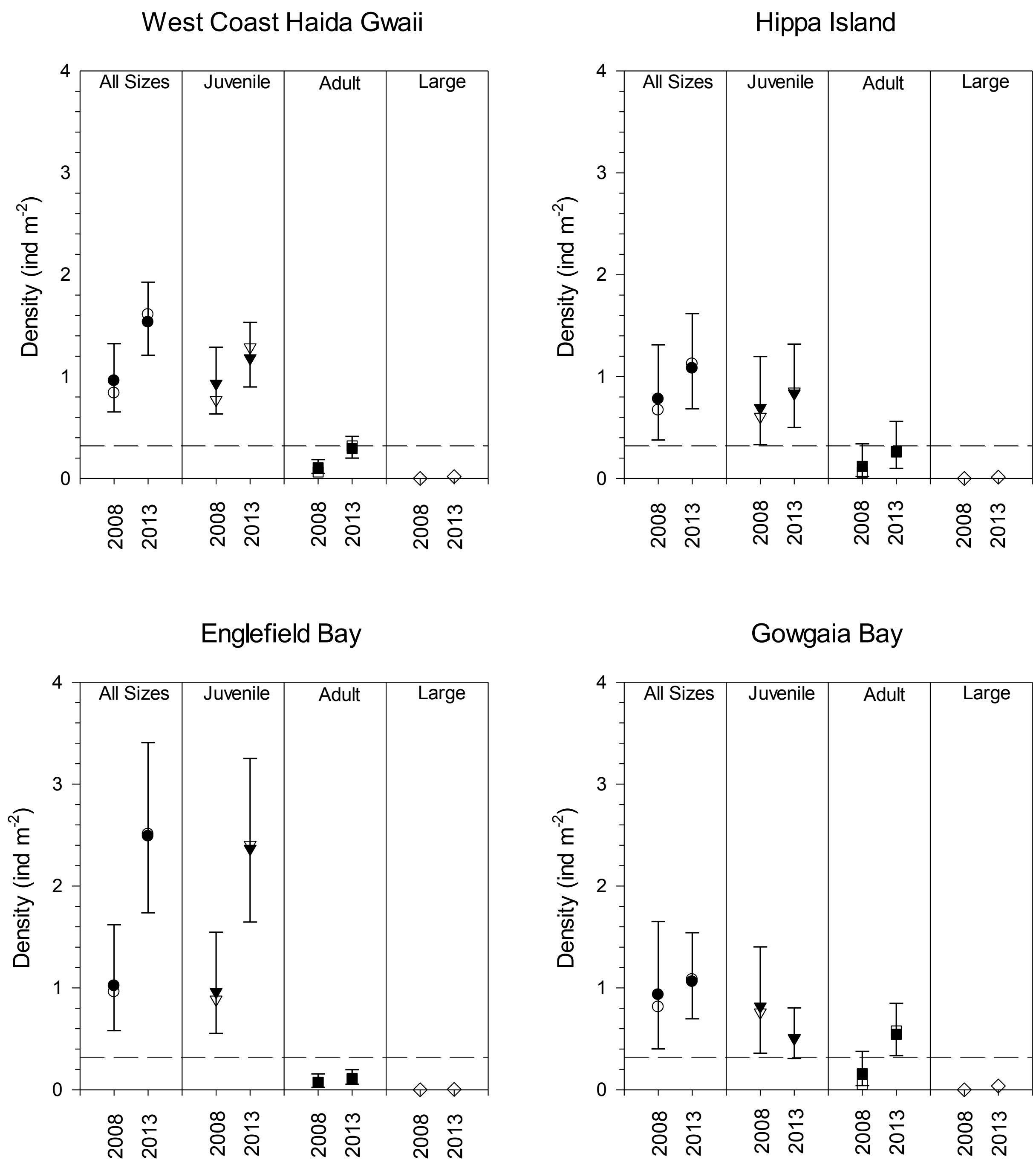


Figure 7. Observed (open symbols) and Estimated (filled symbols) mean density (individuals m^{-2}) of Northern Abalone at index sites in: the entire West Coast Haida Gwaii Region, Hippa Island, Englefield Bay, and Gowgaia Bay for surveys conducted in 2008 and 2013. Estimated density values are mean ± 95% credible interval. Data are shown for the size classes: 'All', 'Juvenile' (< 70 mm SL), 'Adult' (≥ 70mm SL), and 'Large' (≥ 100 mm SL). The dashed line indicates a density of 0.32 ind m^{-2}, the Population and Distribution Objective for the Adult size class from the Action Plan (DFO, 2012). Only observed densities are shown for the Large size class because Large Abalone were either absent (2008) or present in very low numbers (2013).

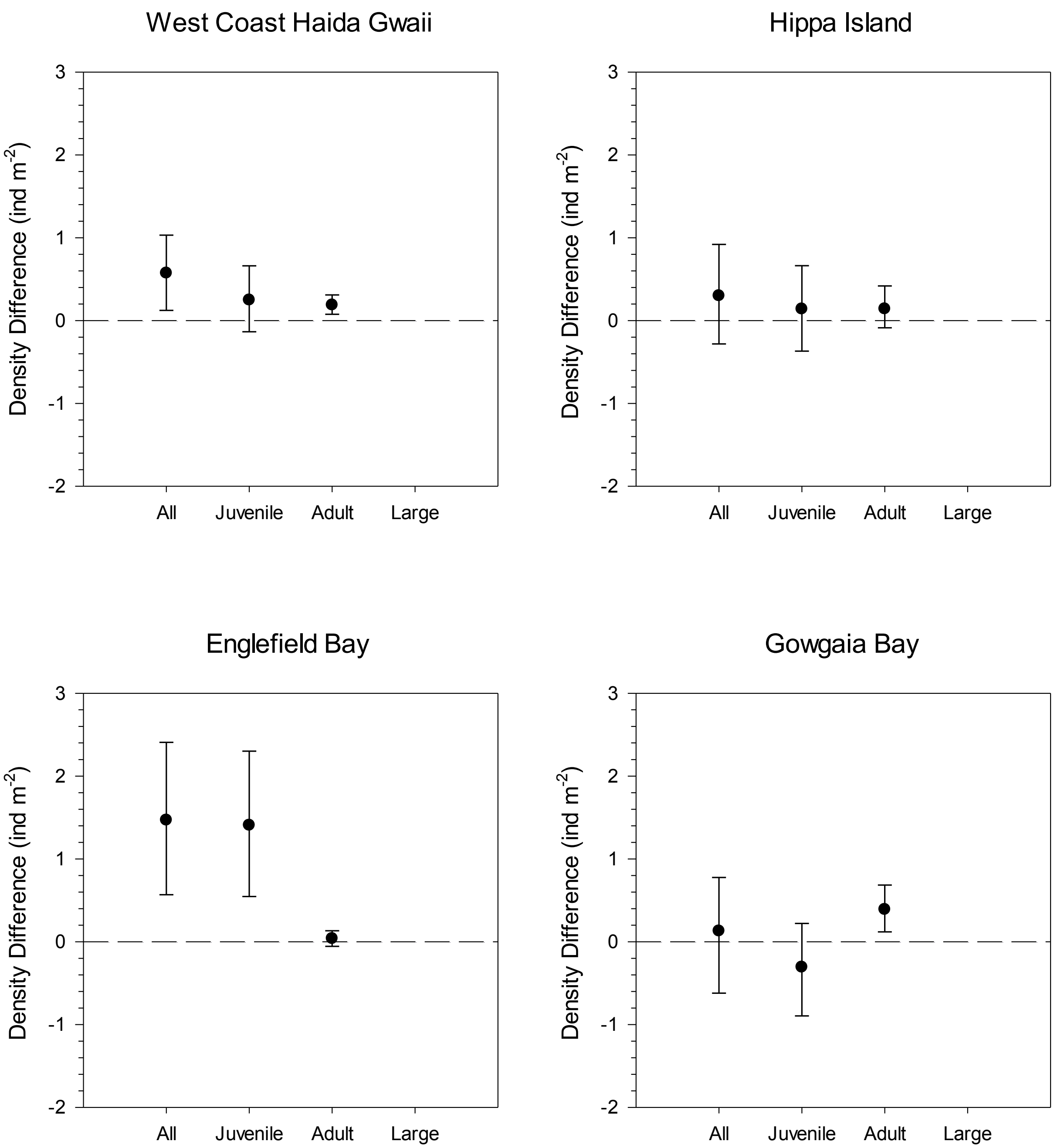


Figure 8. Estimated mean density difference (individuals m^{-2}) of Northern Abalone at index sites in: the entire West Coast Haida Gwaii Region, Hippa Island, Englefield Bay, and Gowgaia Bay. Density difference values are mean ± 95% credible interval. Data are shown for the size classes: 'All', 'Juvenile' (< 70 mm SL), 'Adult' (≥ 70mm SL), and 'Large' (≥ 100 mm SL). Credible interval values above zero indicate a significant increase in density and those below zero indicate a significant decrease in density between 2008 and 2013, when taking into account the uncertainty associated with density estimates in each year. Due to the absence of Large Abalone in 2008, density differences could not be estimated for this size class.

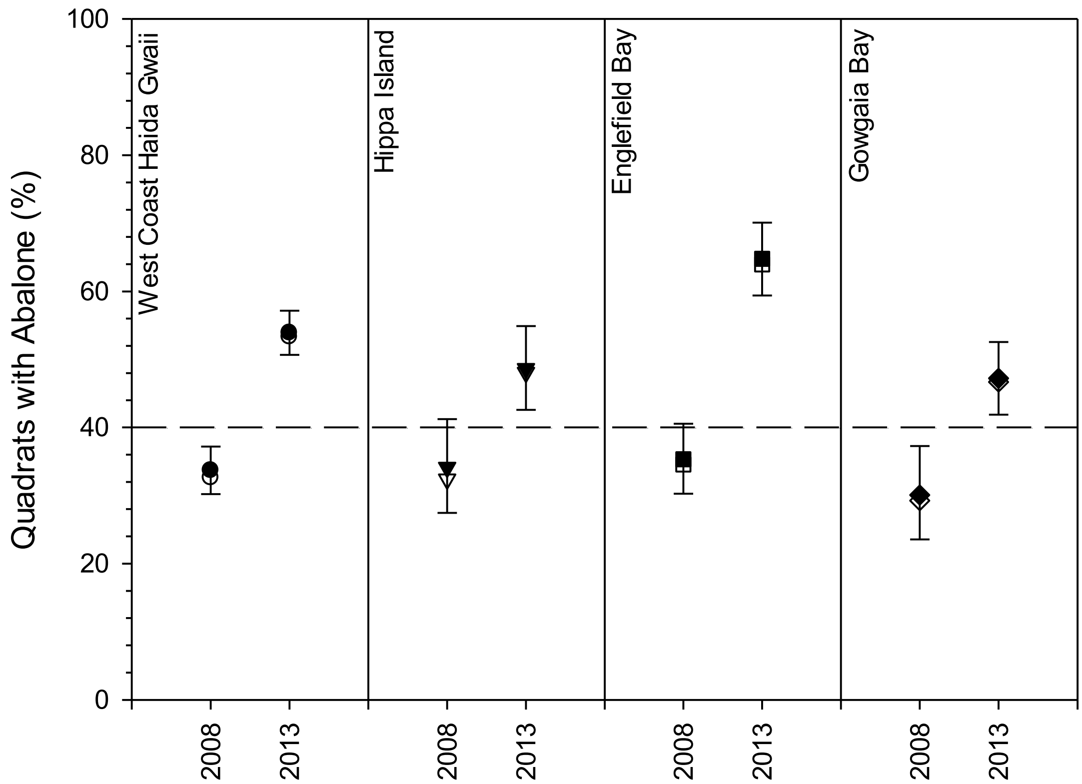


Figure 9. The observed (open symbols) and estimated (filled symbols) mean percentage of quadrats containing at least one Northern Abalone for: the entire West Coast Haida Gwaii Region, Hippa Island, Englefield Bay, and Gowgaia Bay. Values for the estimated percentage of quadrats are mean ± 95% credible interval. The dashed line is at 40%, the Population and Distribution Objective for the percentage of quadrats with Abalone

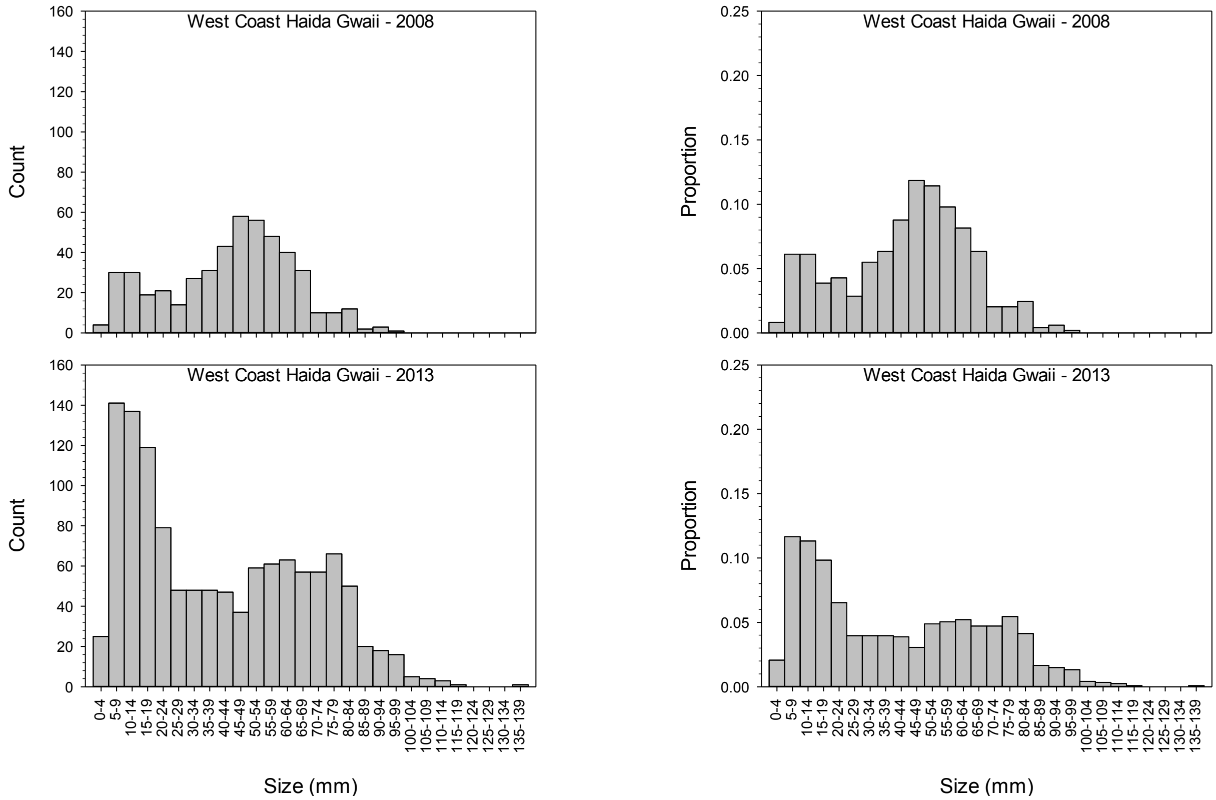


Figure 10. Size frequency histograms of Northern Abalone measured during index site surveys at all Sites on the West Coast of Haida Gwaii in 2008 and 2013. The number of Abalone measured and the relative proportion are shown for each 5-mm size bin.

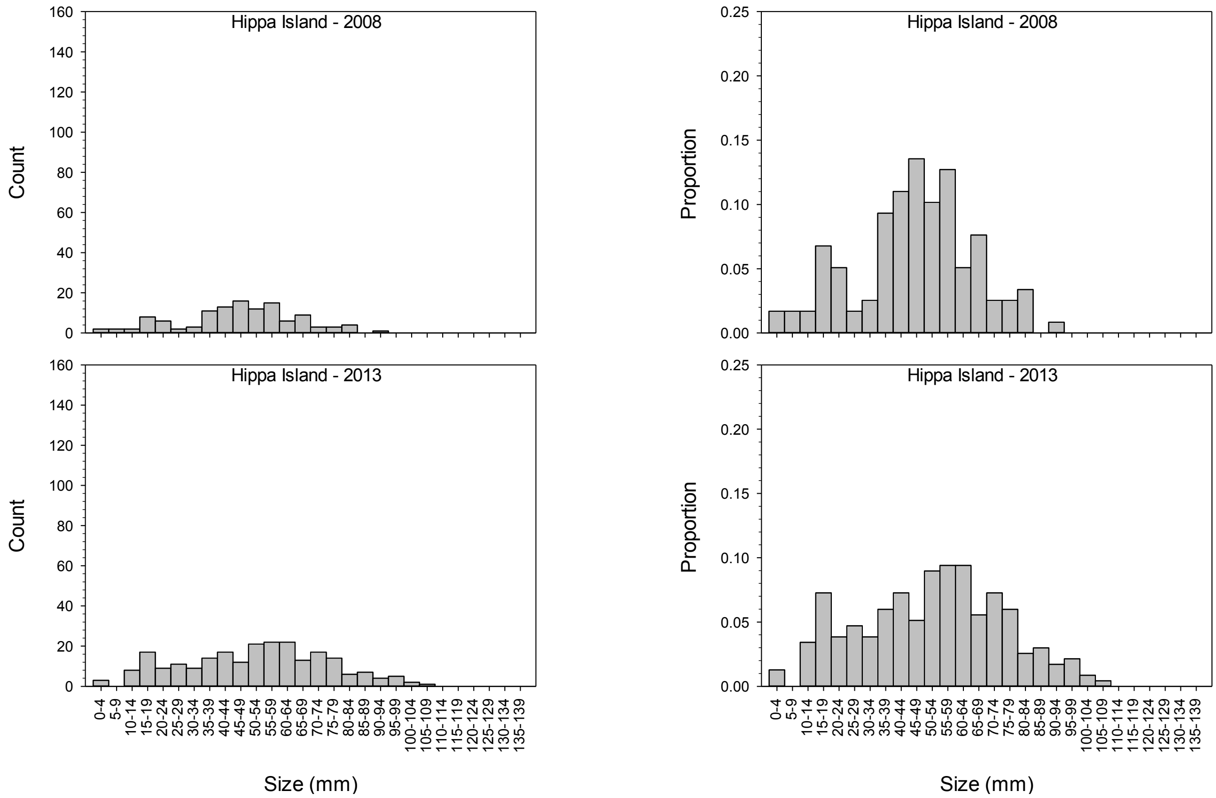


Figure 11. Size frequency histograms of Northern Abalone measured at Hippa Island, Englefield Bay, and Gowgaia Bay during index site surveys in 2008 and 2013. The number of Abalone measured and the proportion are shown for each 5-mm size bin in 2008 and 2013.

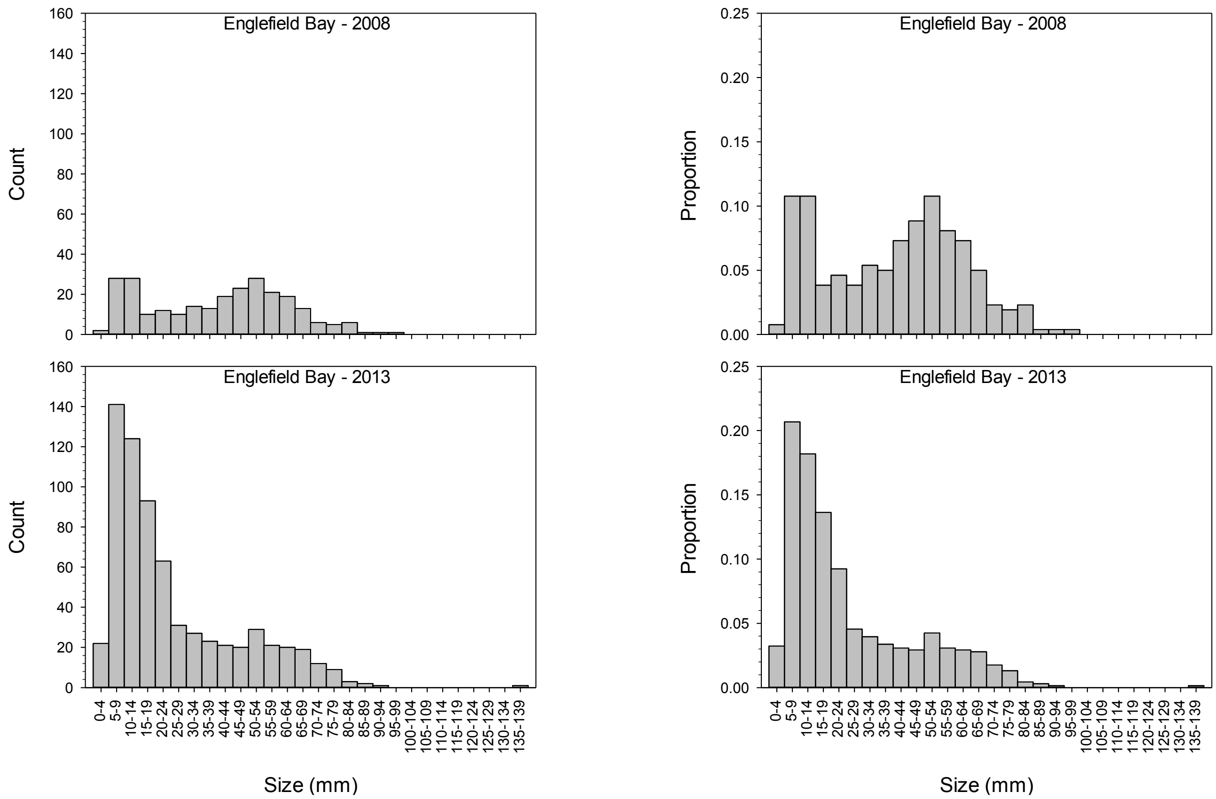


Figure 11. Con’t.

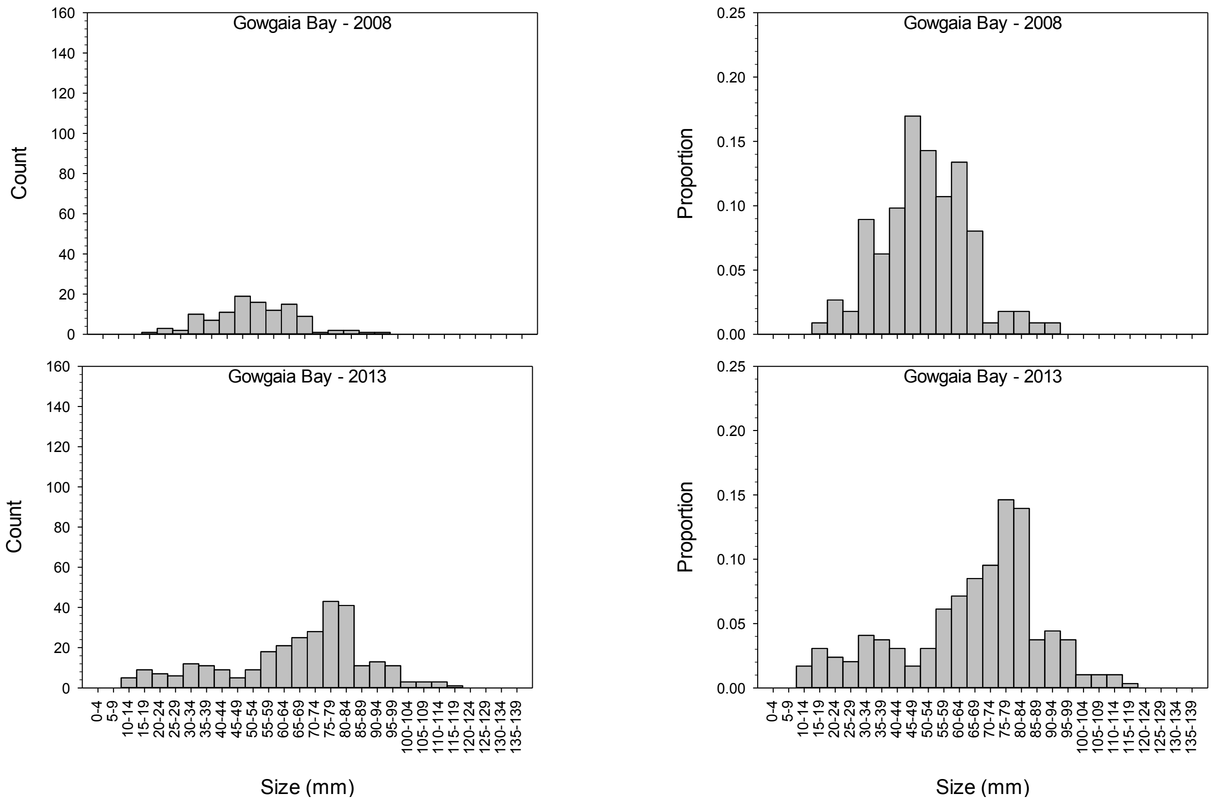


Figure 11. Con't.

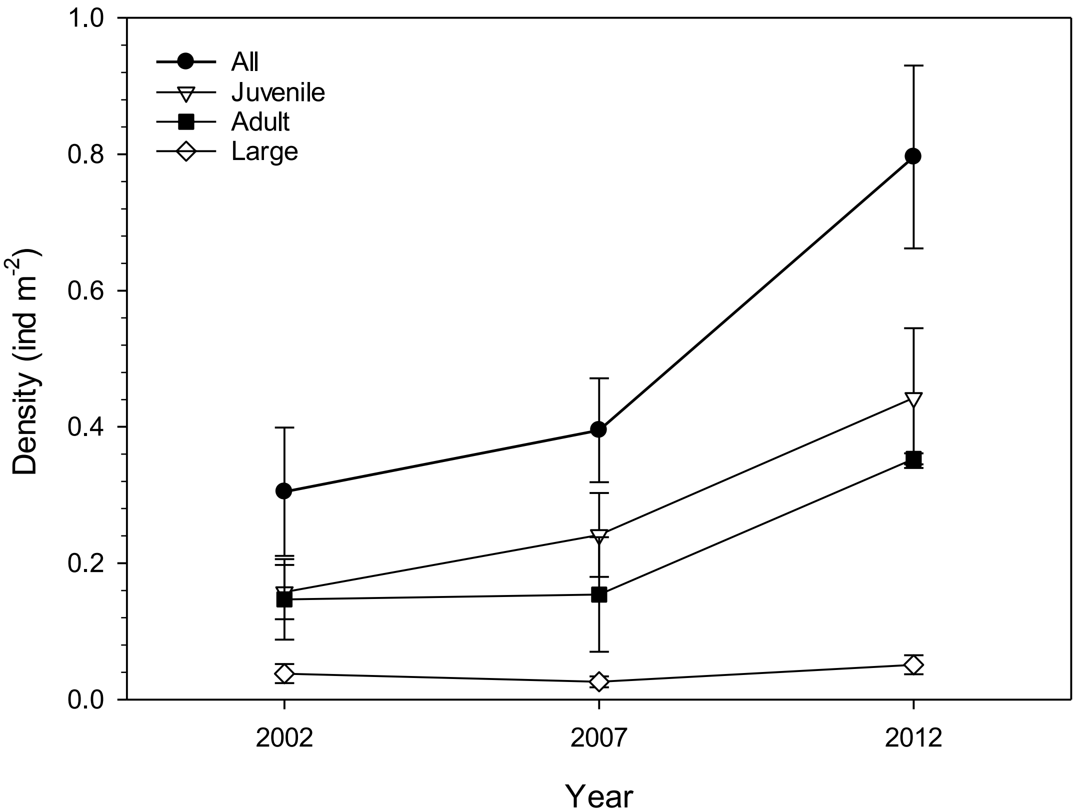


Figure 12. Density of Northern Abalone observed at index sites for the entire East Coast Haida Gwaii Region in 2002, 2007, and 2012. Values are mean density (individuals m^{-2}) ± SE for the size classes: 'All' (≥ 20 mm SL), 'Juvenile' (≥ 20 mm and < 70 mm SL), 'Adult' (≥ 70 mm SL) and 'Large' (≥ 100 mm SL). Area is used as the sampling unit for mean and SE calculations.

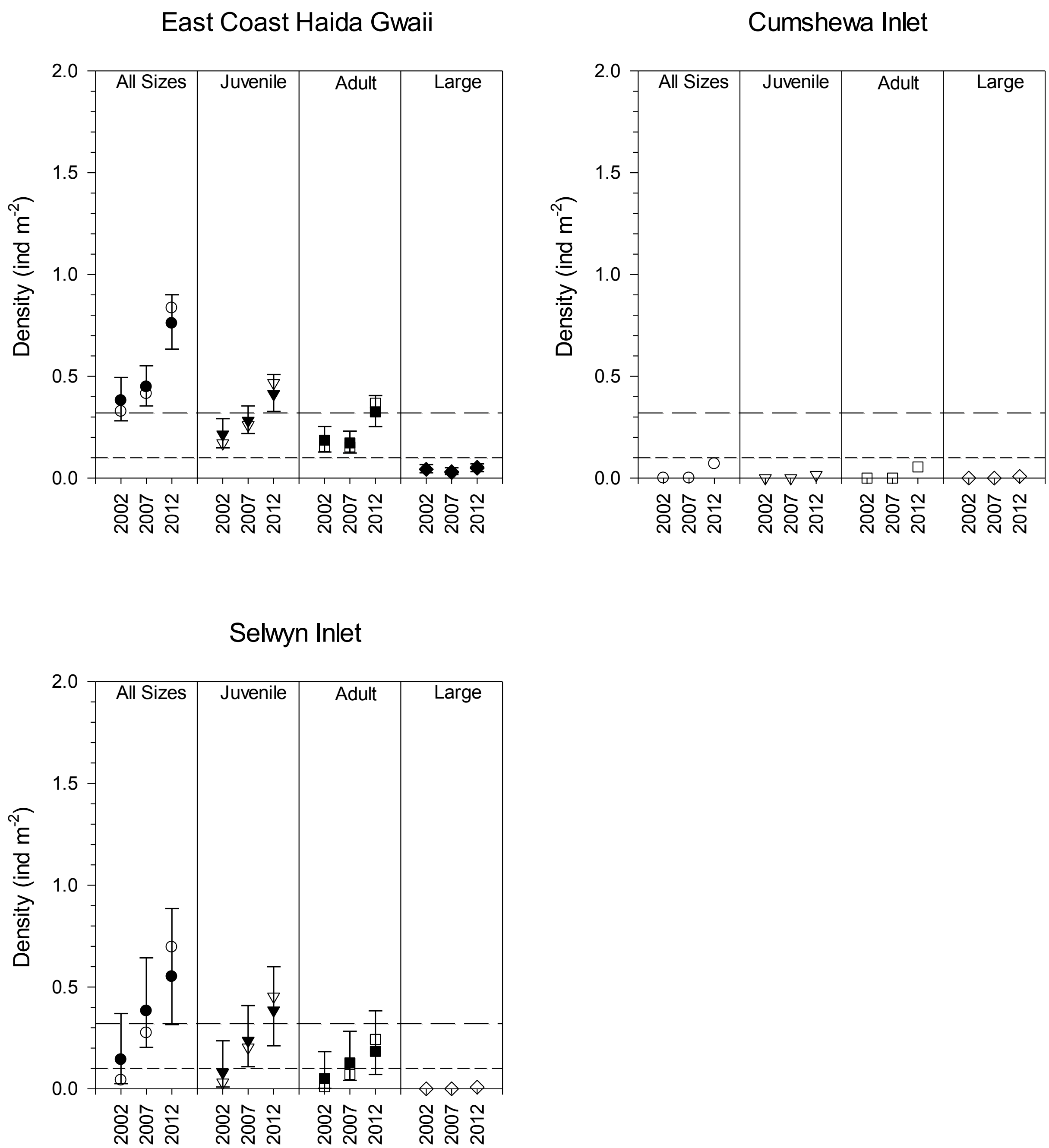


Figure 13. Estimated density of Northern Abalone at Index Sites for the entire East Coast Haida Gwaii Region, as well as for each individual Area for the years 2002, 2007, and 2012. Estimated densities are given for the size classes: ‘All’ (≥ 20 mm SL), ‘Juvenile’ (≥ 20 mm and < 70 mm SL), ‘Adult’ (≥ 70 mm SL) and ‘Large’ (≥ 100 mm SL). Values are mean estimated density ± 95% credible interval (filled symbols). The long dashed line indicates 0.32 ind m^{-2} (the Population and Distribution Objective for Adult Abalone) and the short dashed line indicates 0.1 ind m^{-2} (the Population and Distribution Objective for Large Abalone). Open symbols are the observed values for reference.

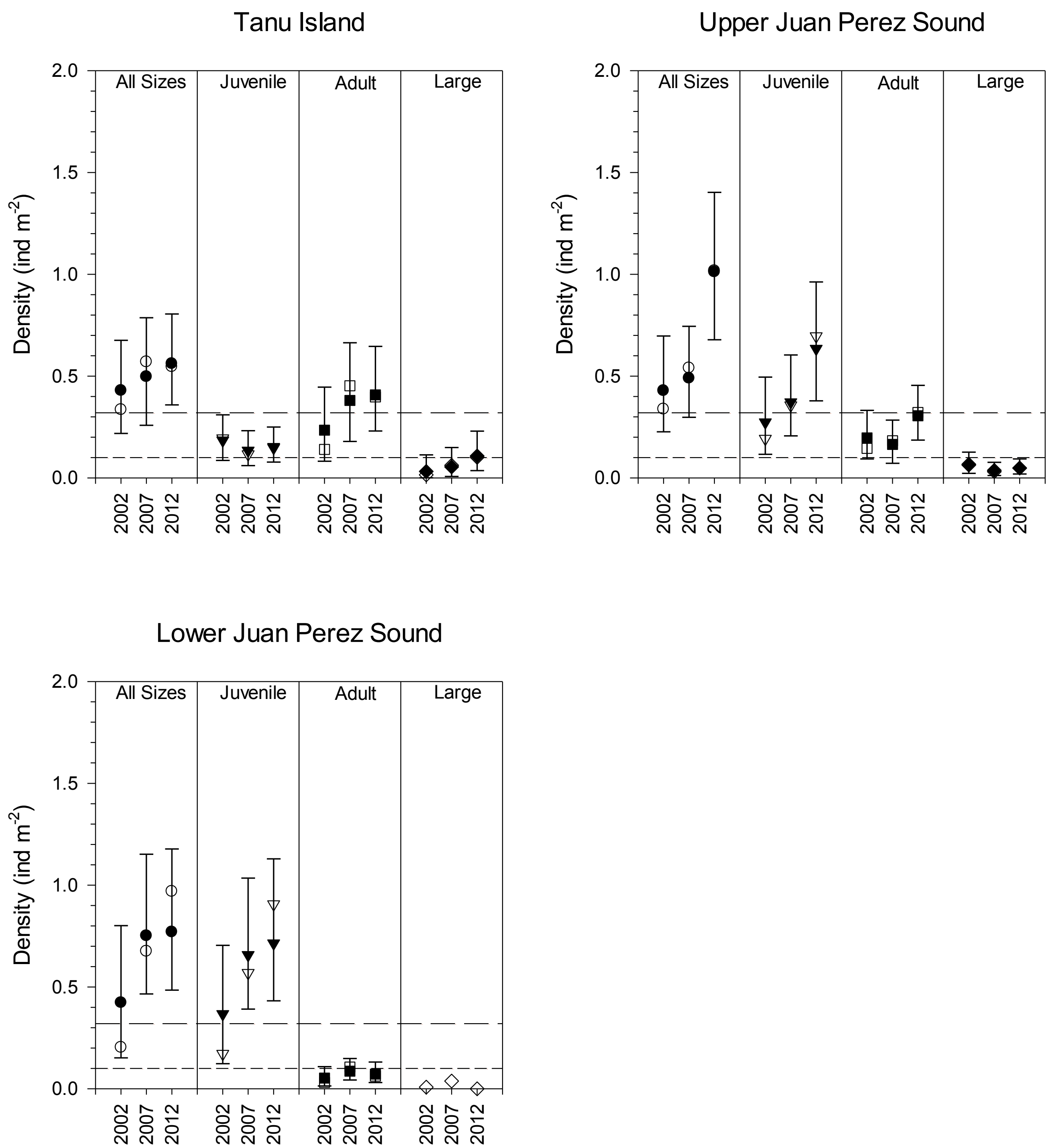


Figure 13. Con't.

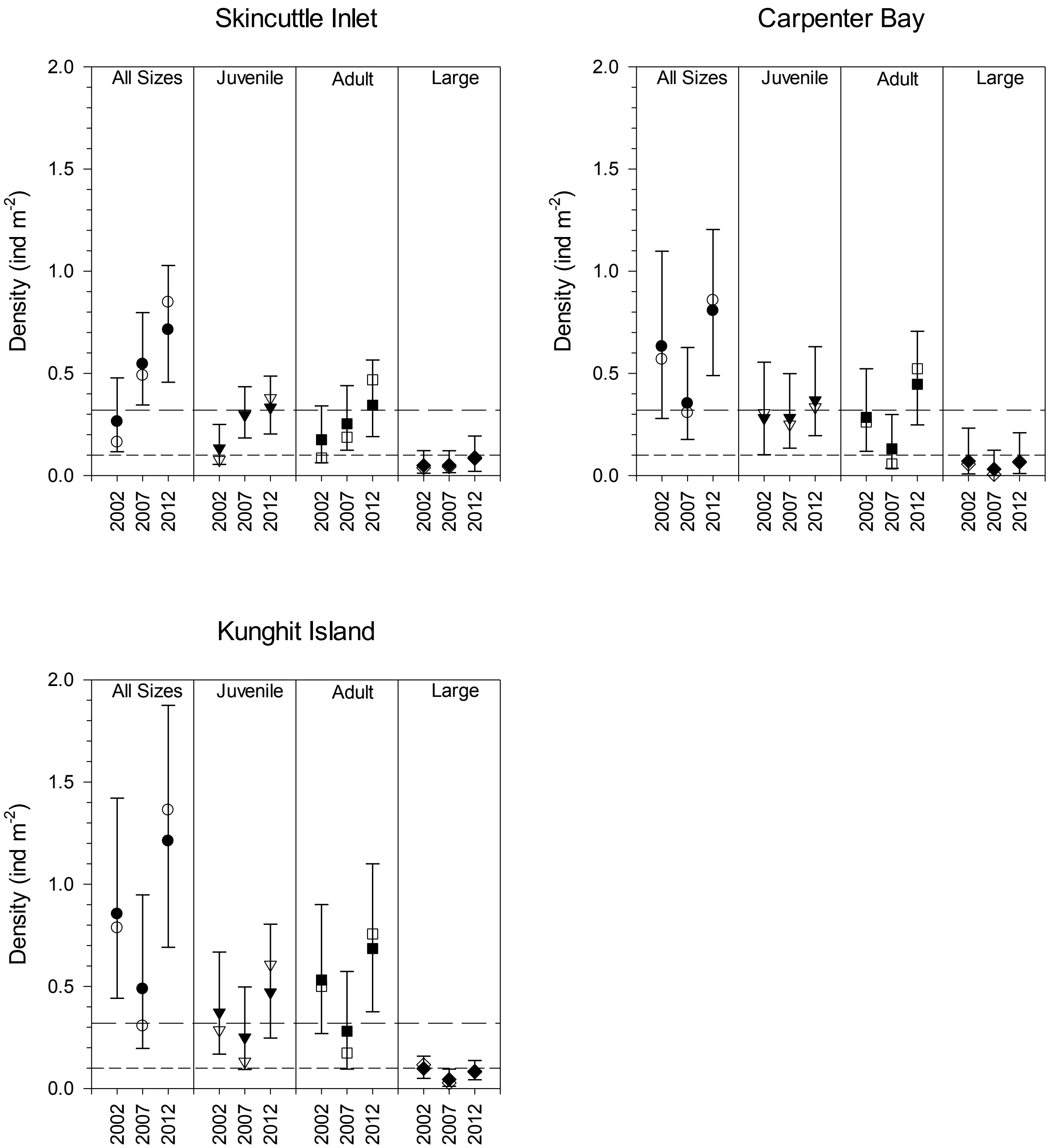


Figure 13. Con't.

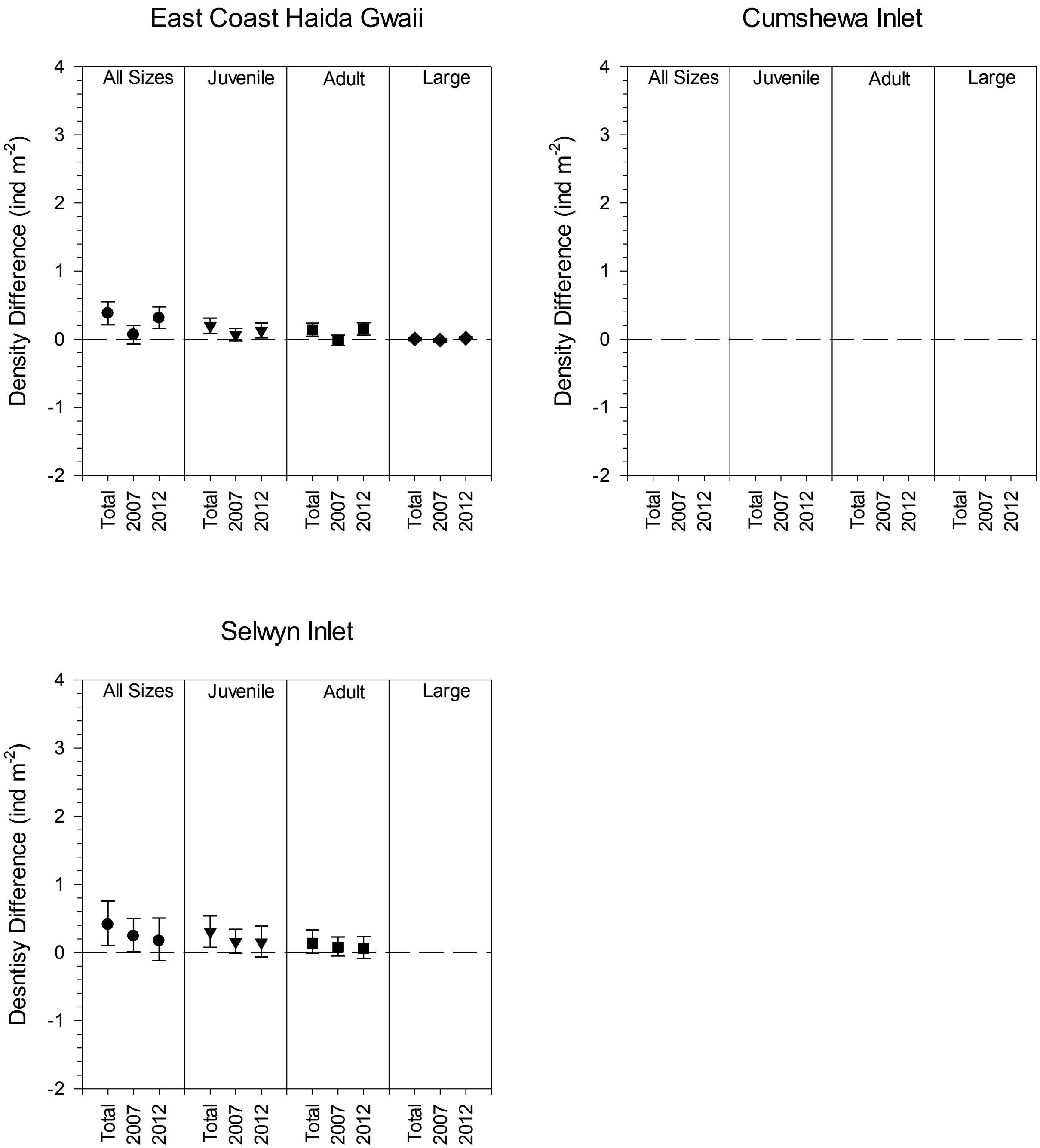


Figure 14. Estimated density difference of Northern Abalone at index sites for the entire East Coast Haida Gwaii Region, as well as for each individual Area. Estimated density difference is shown for the size classes: 'All' (≥ 20 mm SL), 'Juvenile' (≥ 20 mm and < 70 mm SL), 'Adult' (≥ 70 mm SL) and 'Large' (≥ 100 mm SL). Values are mean estimated density difference ± 95% credible interval between a given survey year and the survey year prior. 'Total' is the estimated density difference between 2012 and 2002. Credible intervals that overlap the dashed line indicate no change in density. The panel for Cumshewa Inlet is blank because not enough Abalone were observed to calculate an estimated density difference.

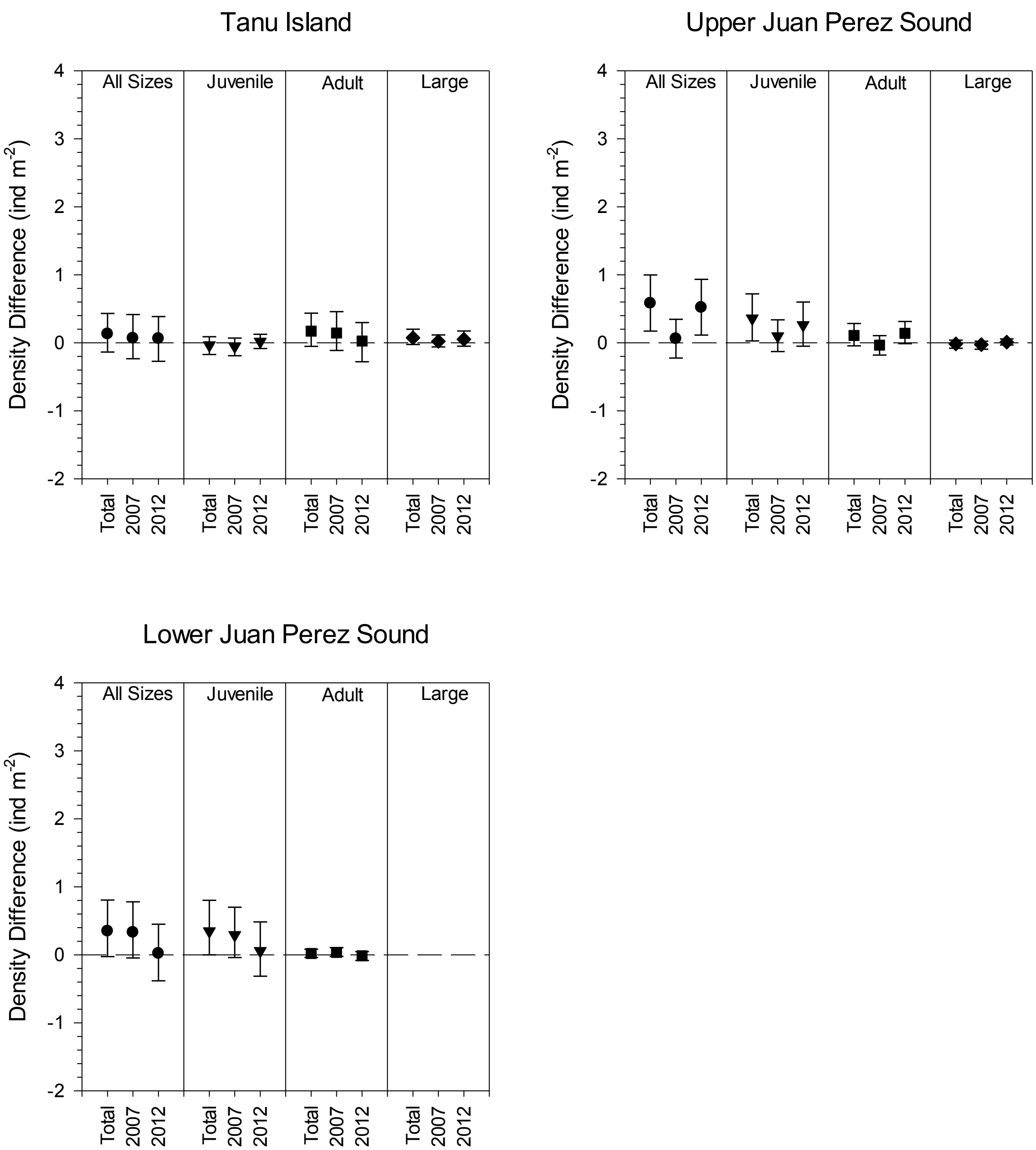


Figure 14. Con't.

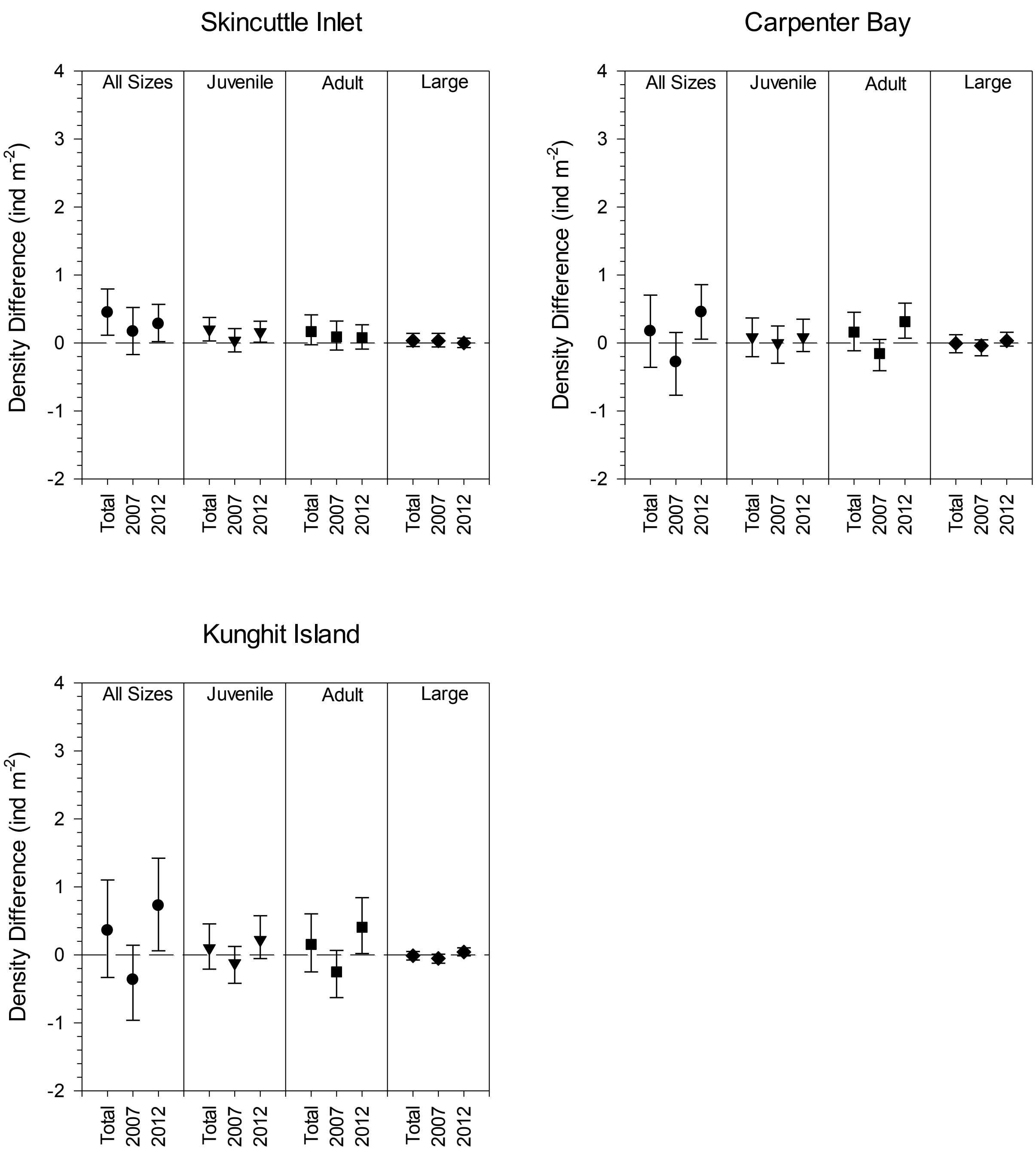


Figure 14. Con’t.

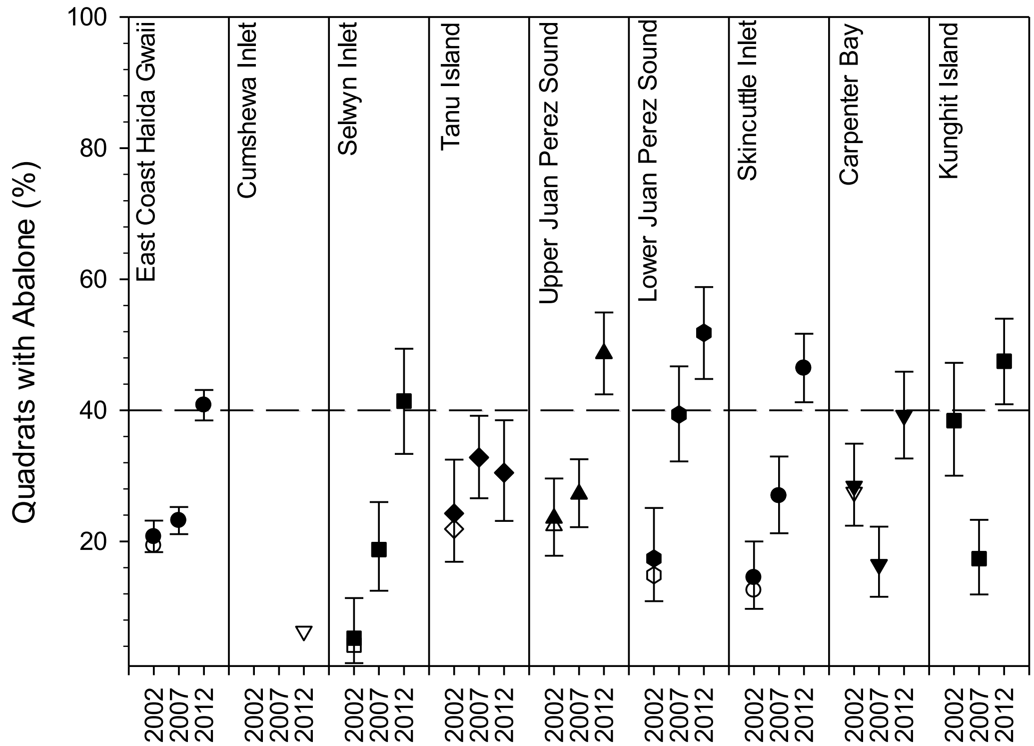


Figure 15. The estimated percentage of quadrats with Northern Abalone for the entire East Coast Haida Gwaii Region, as well as for each individual Area. Values are the mean estimated percentage of quadrats ± 95% credible interval (filled symbols) and the observed percentage of quadrats (open symbols) with at least one Northern Abalone. The dashed line is at 40%, the Population and Distribution Objective for the percentage of quadrats with Abalone.

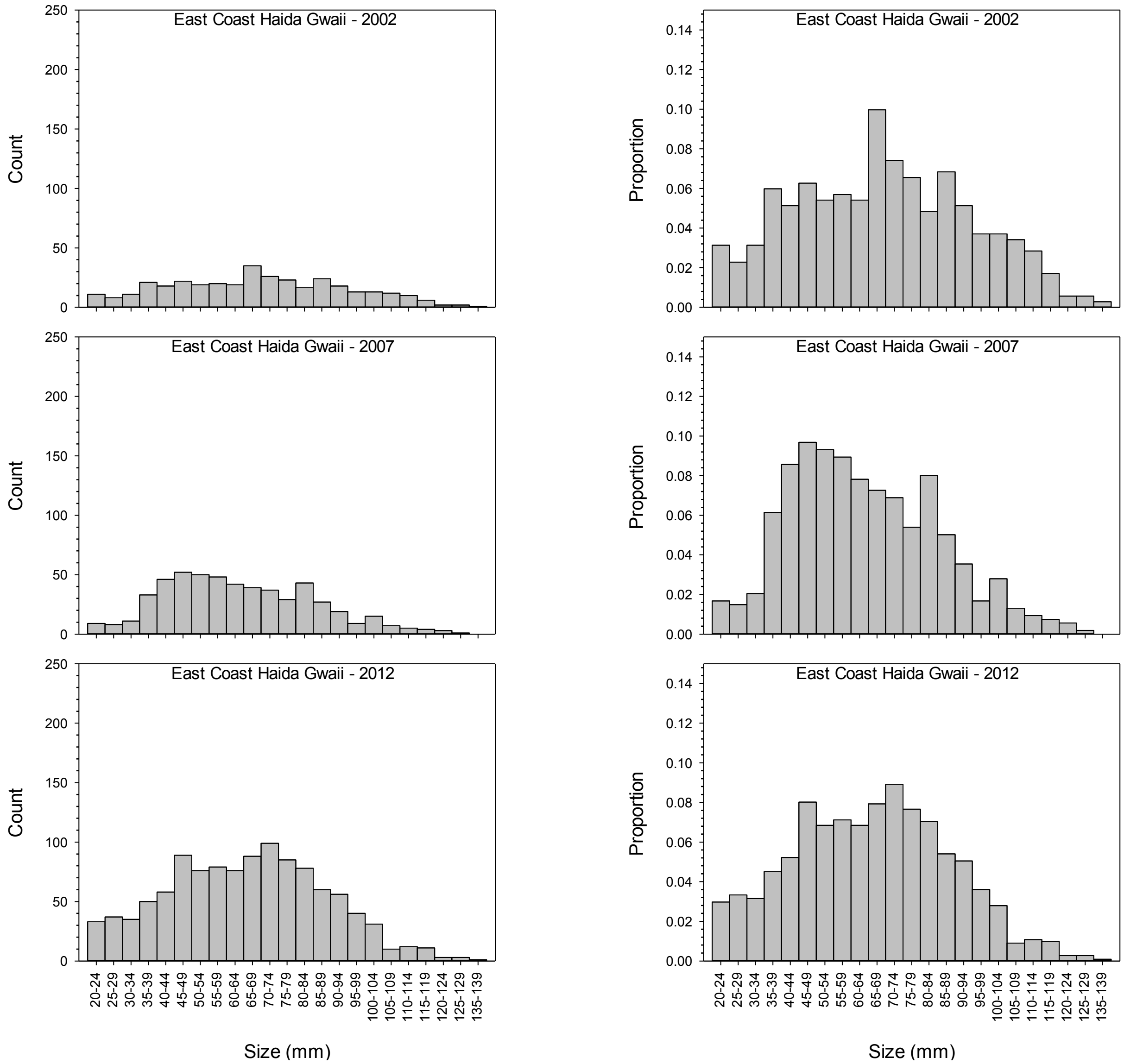


Figure 16. Size frequency histograms of Northern Abalone between 20 and 139 mm shell length, measured during index site surveys on the East Coast of Haida Gwaii from 2002 to 2012. The absolute number of Abalone measured and the relative proportion are shown for each 5-mm size bin. Data are hedged at 20 mm due to the cryptic nature and difficulty in detecting Abalone smaller than this size. No Abalone greater than 139 mm were observed.

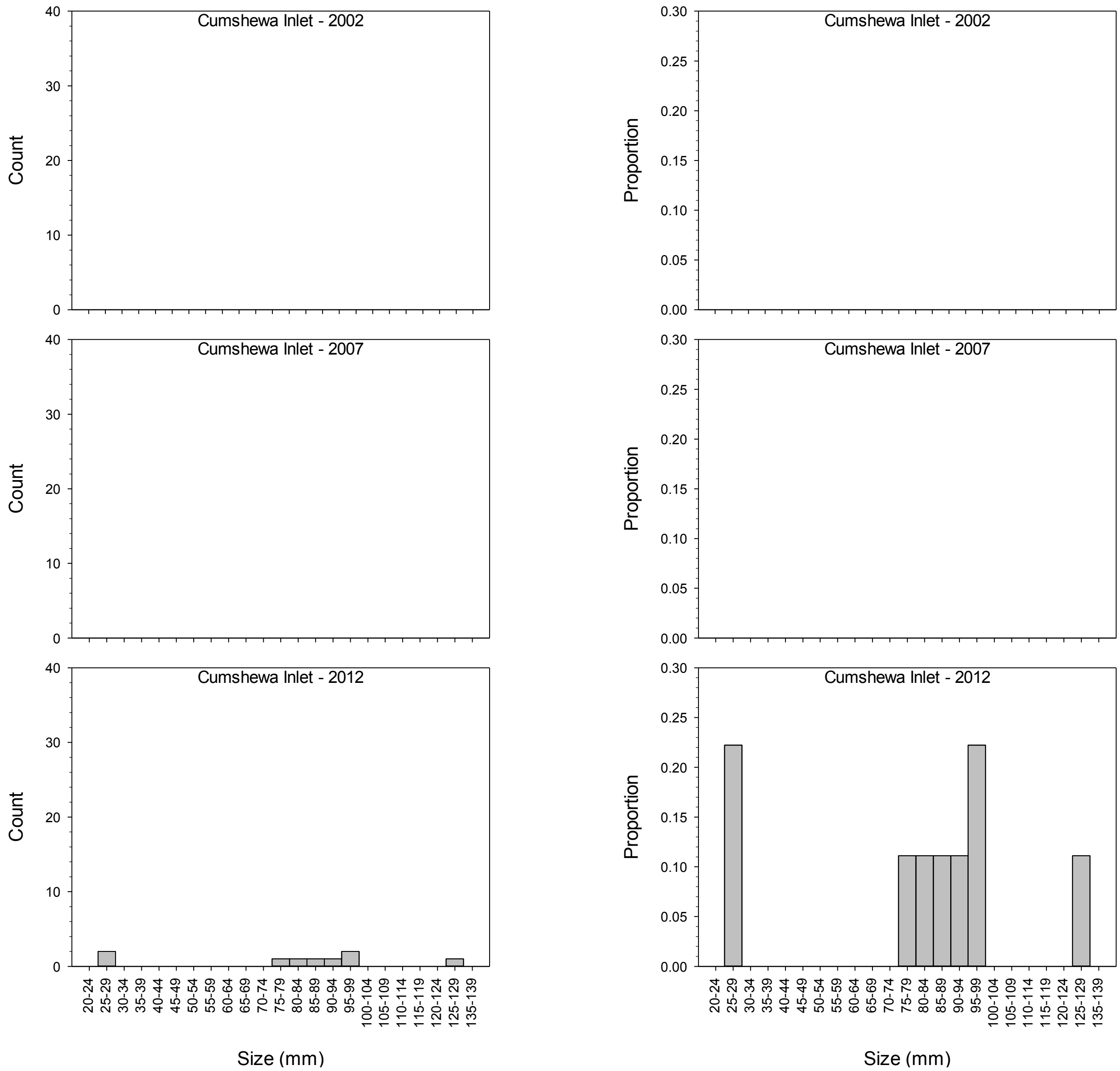


Figure 17. Size frequency histograms of Northern Abalone between 20 and 139 mm shell length, measured during index site surveys for each Area on the East Coast of Haida Gwaii from 2002 to 2012. The absolute number of Abalone measured and the relative proportion are shown for each 5-mm size bin. Data are hedged at 20 mm due to the cryptic nature and difficulty in detecting Abalone smaller than this size. No Abalone greater than 139 mm were observed. Panels for Cumshewa Inlet in 2002 and 2007 are blank as no Abalone were observed.

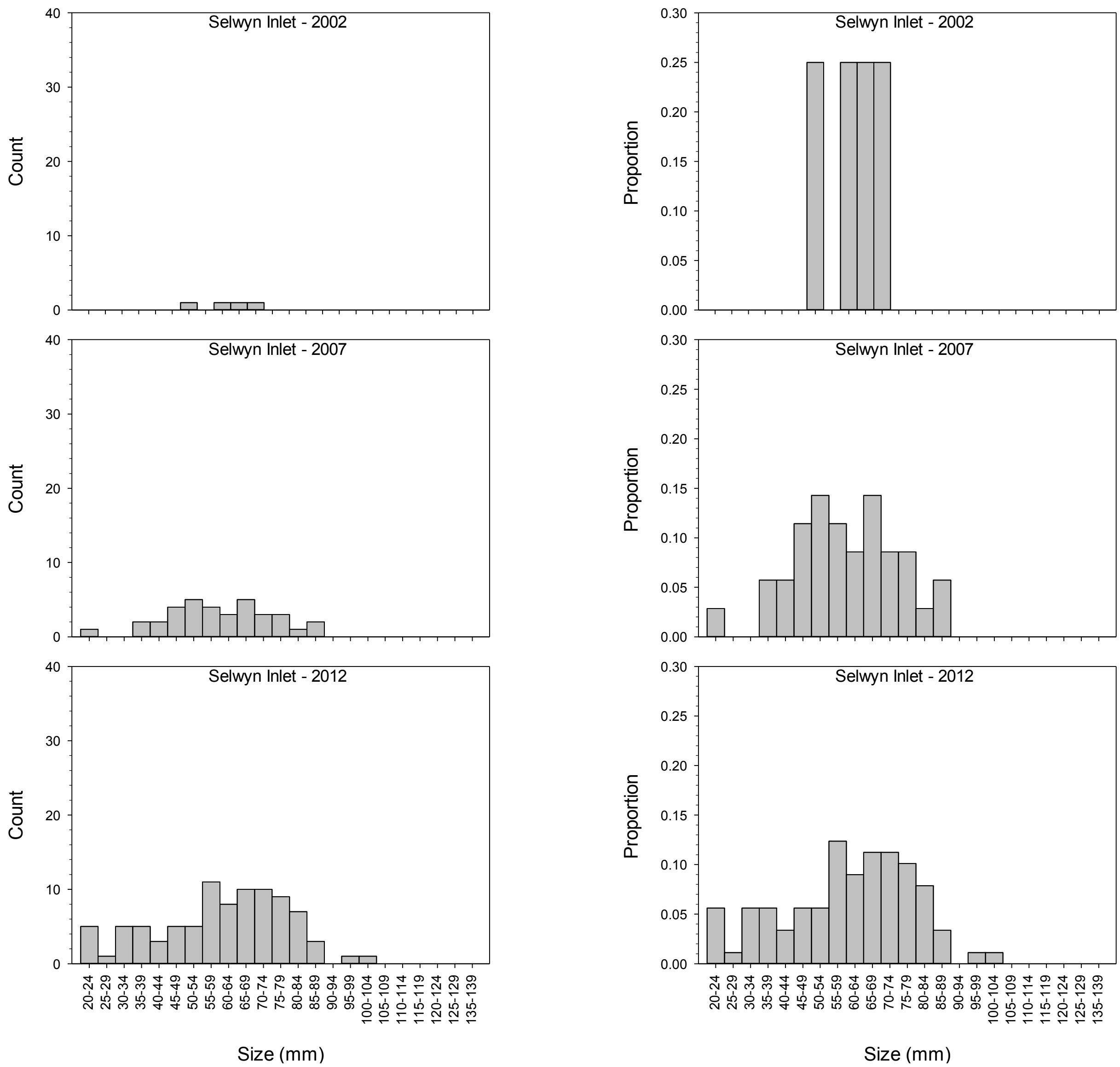


Figure 17. Con't.

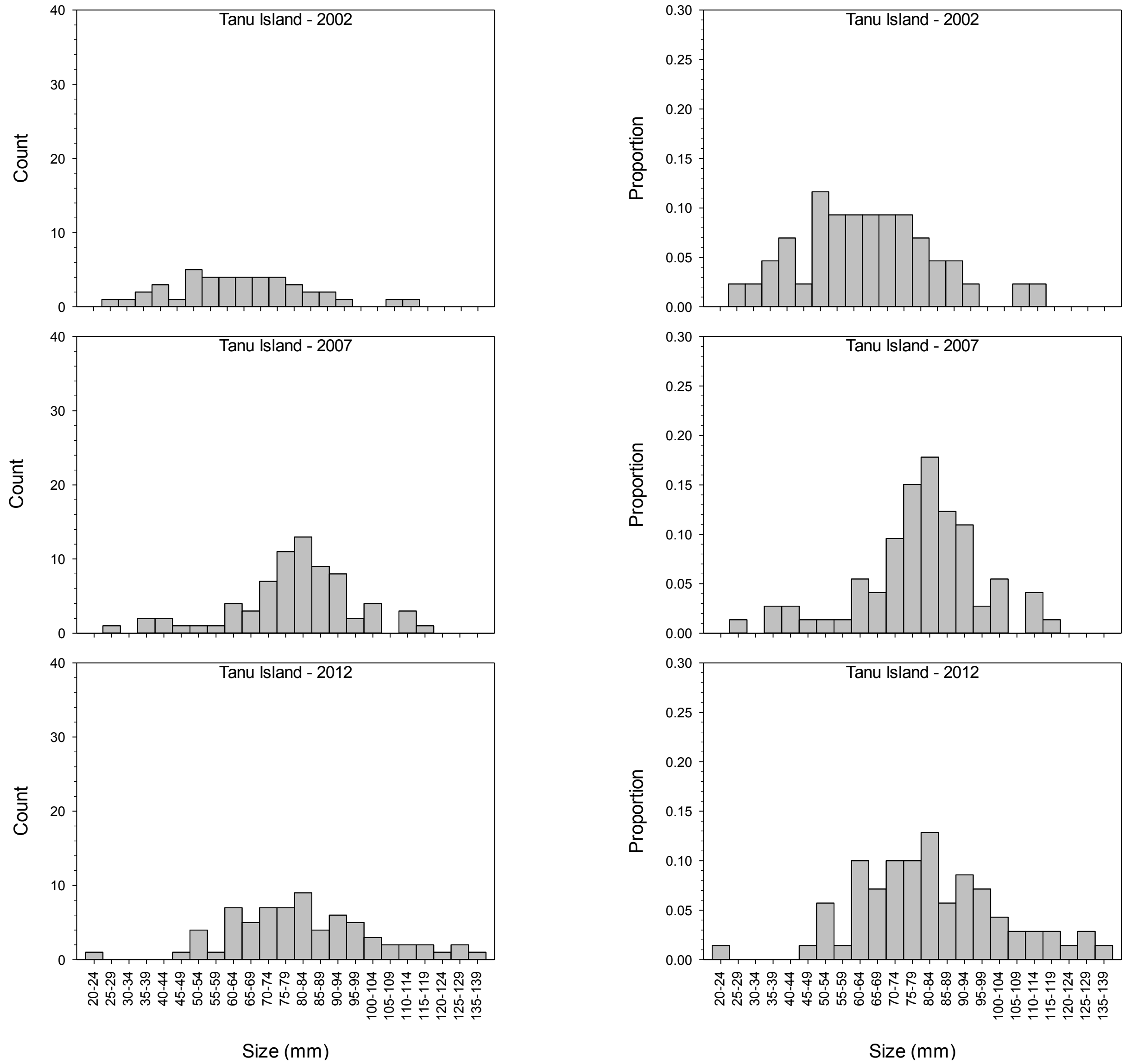


Figure 17. Con't.

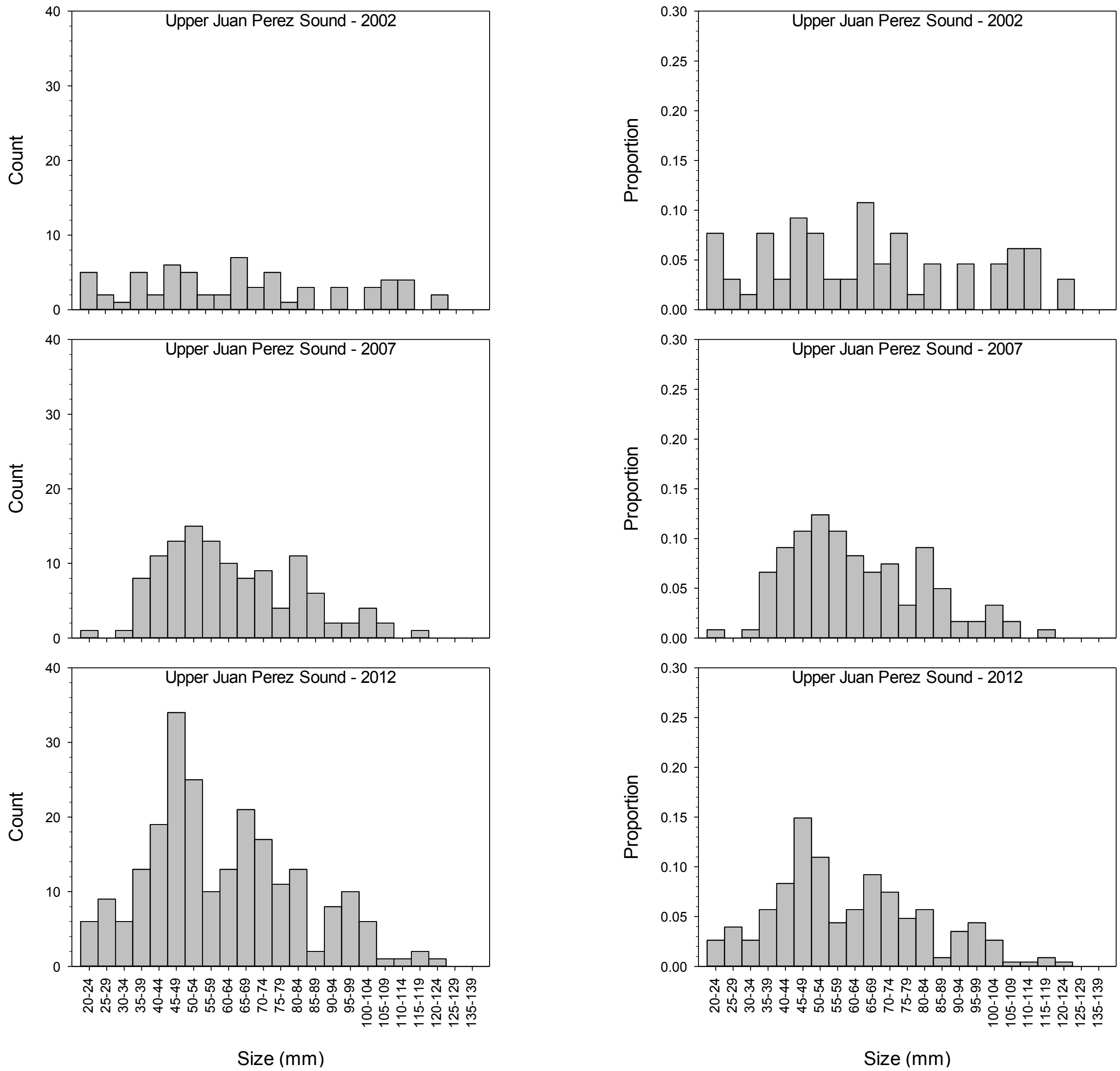


Figure 17. Con't.

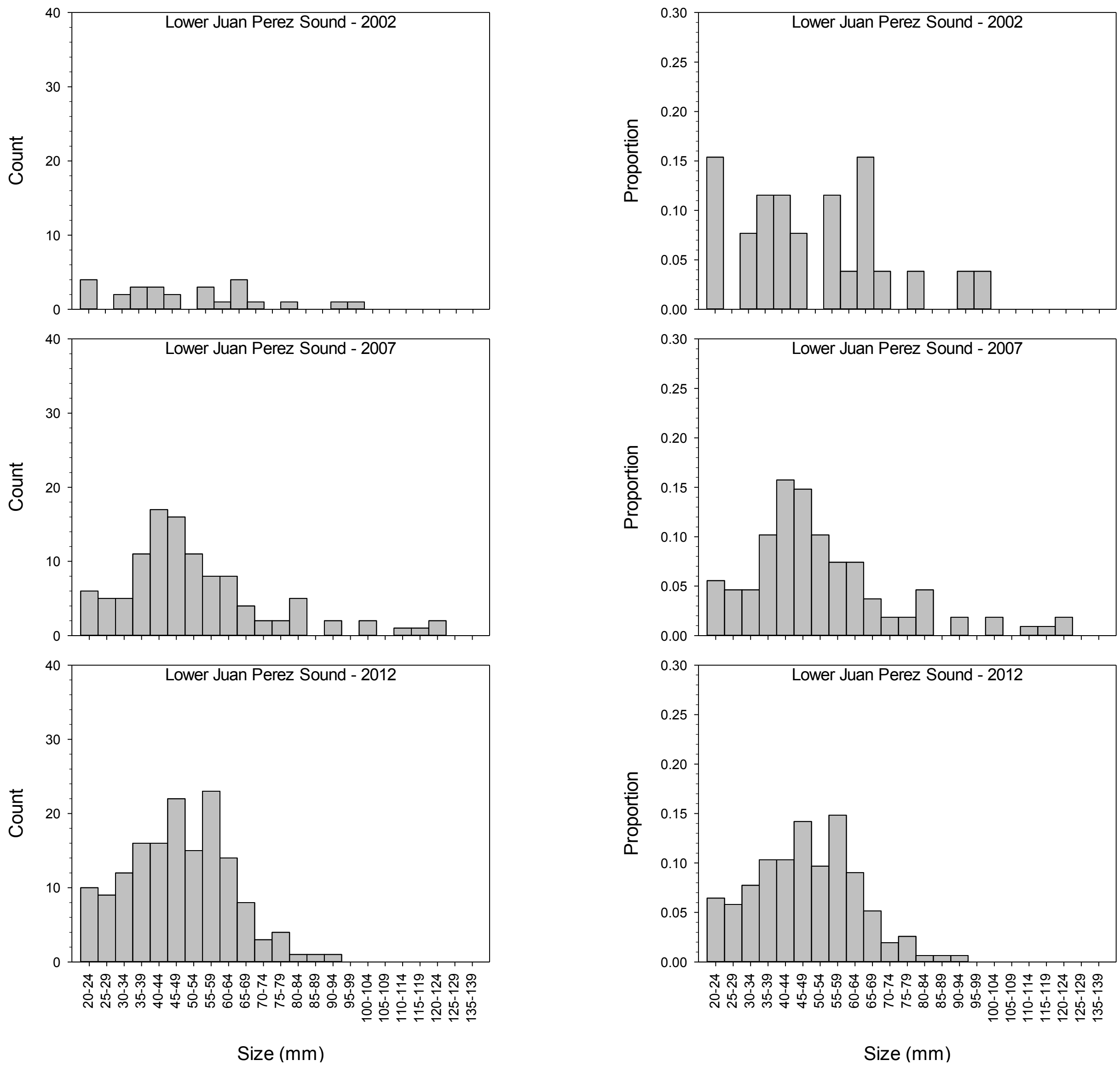


Figure 17. Con't.

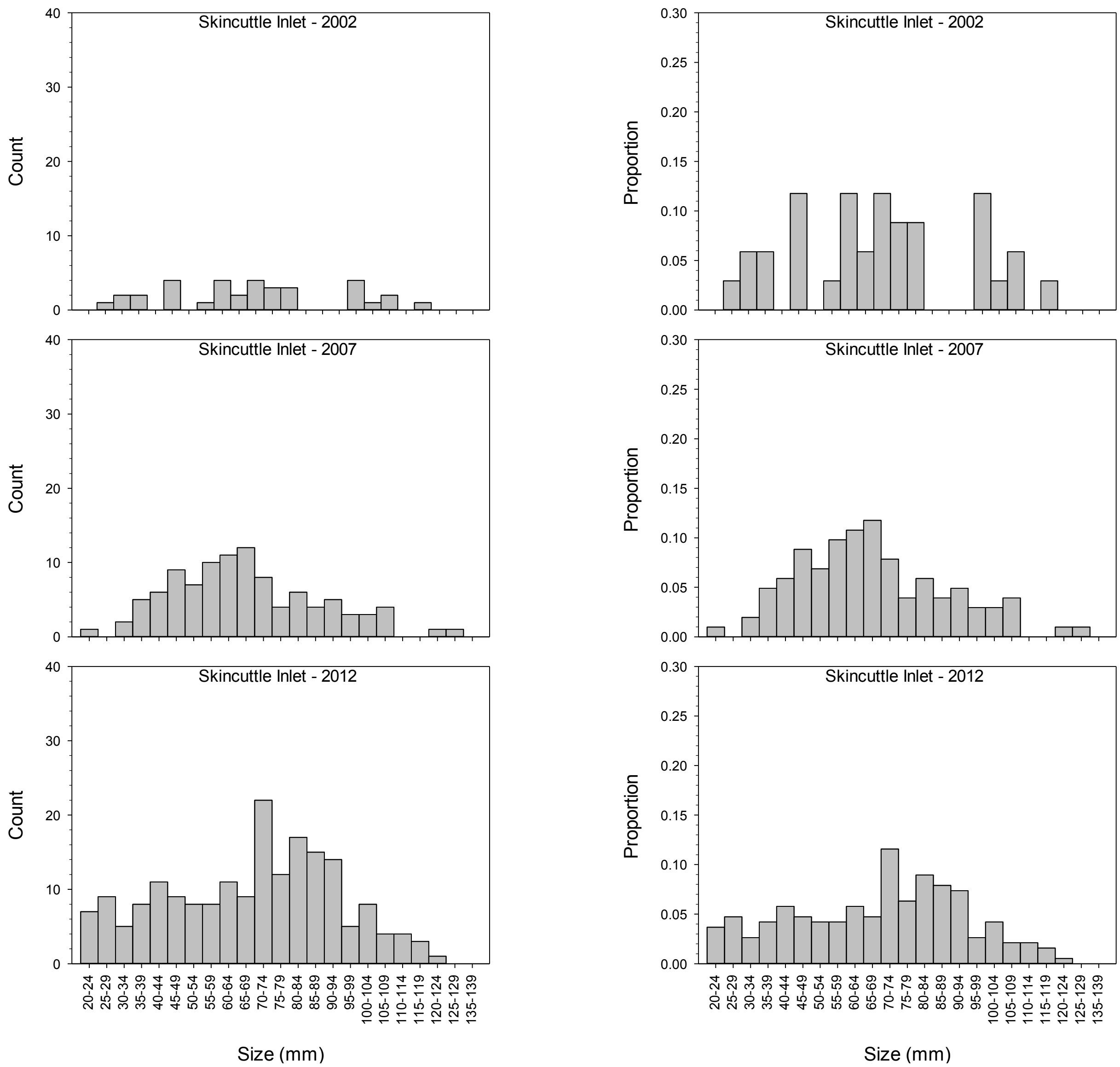


Figure 17. Con't.

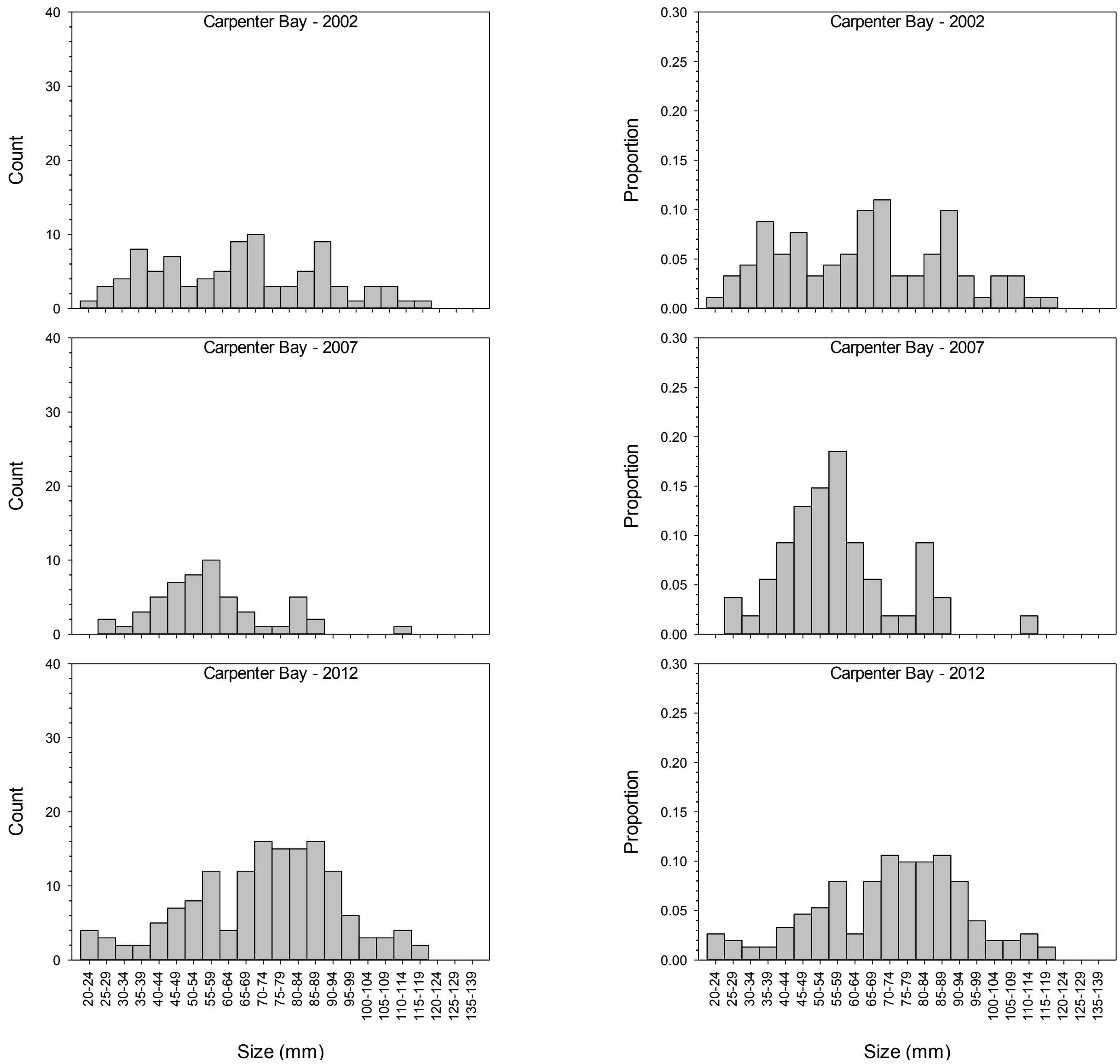


Figure 17. Con't.

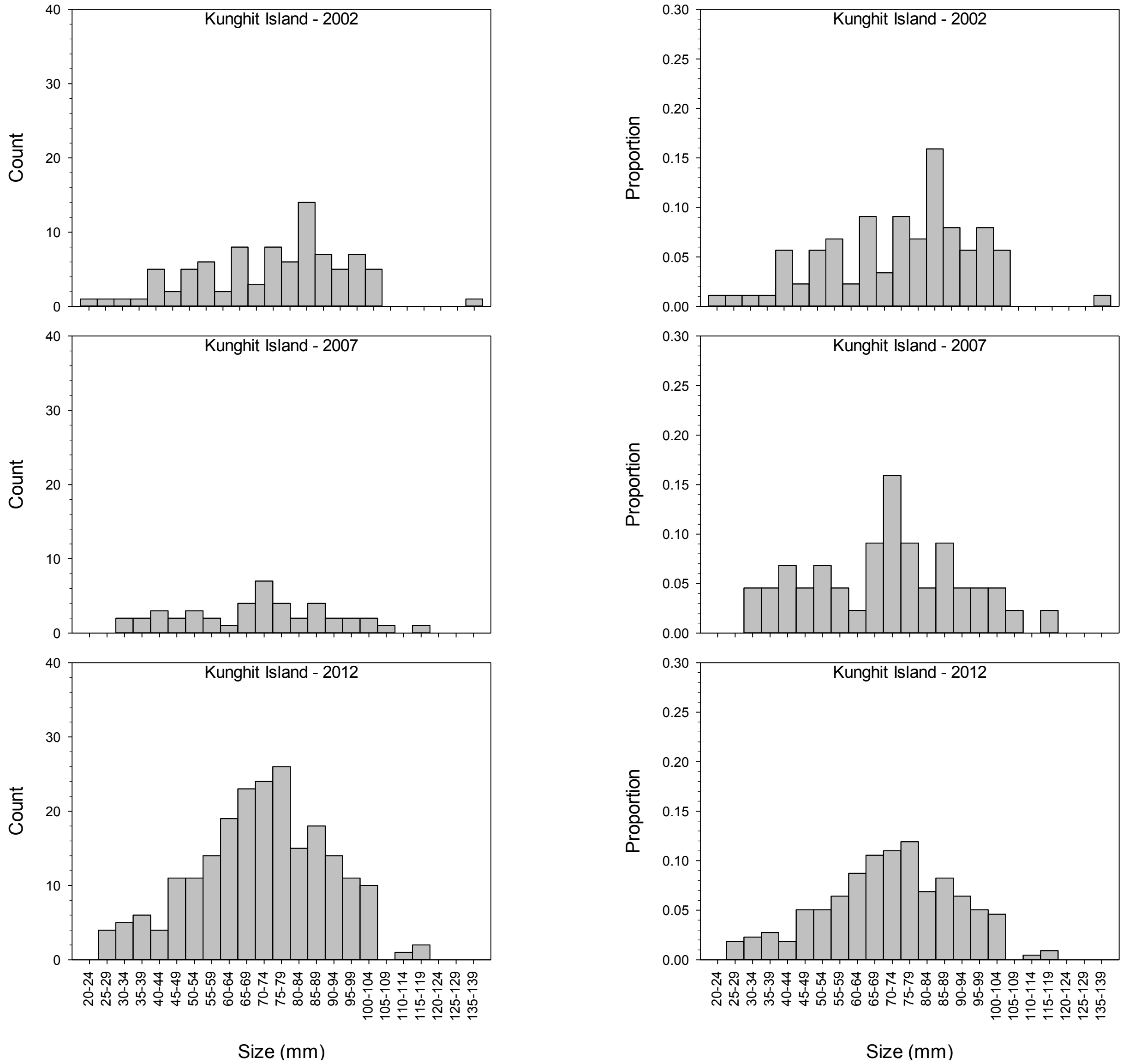


Figure 17. Con't.

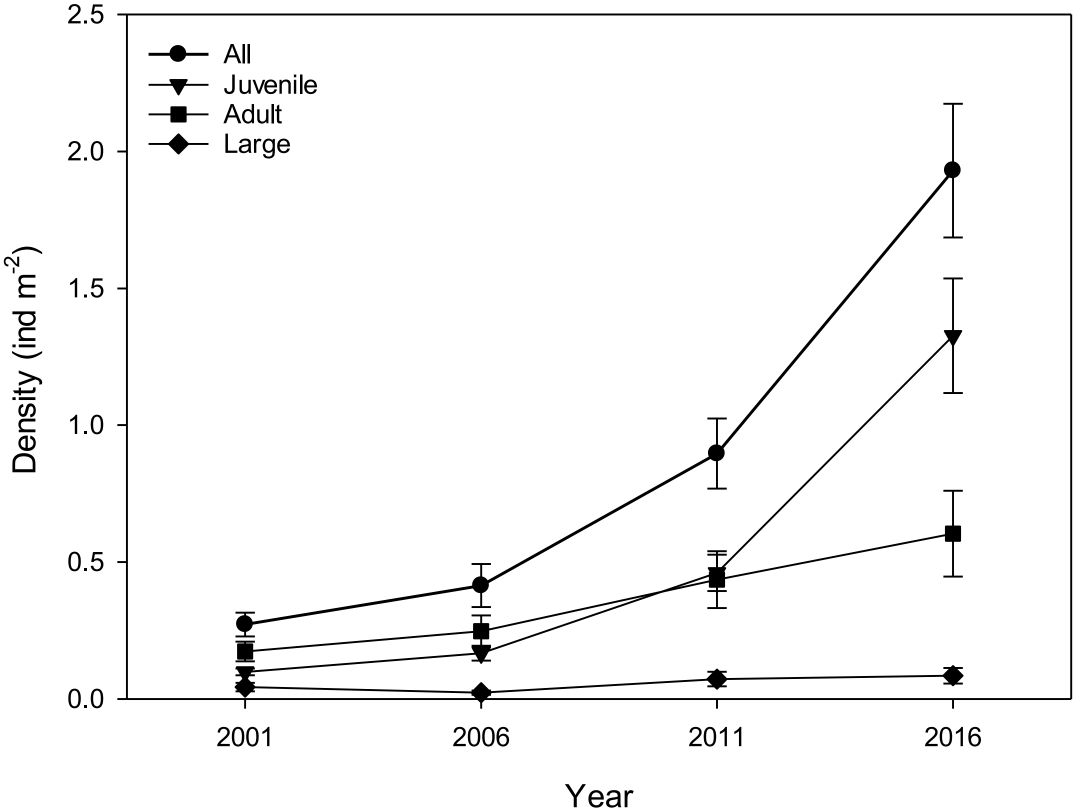


Figure 18. Summary density data for the entire Central Coast Region from Northern Abalone index site surveys 2001-2016. Values are mean observed density (individuals m^{-2}) ± SE for the size classes: 'All' (≥ 20 mm SL), 'Juvenile' (≥ 20 mm and < 70 mm SL), 'Adult' (≥ 70 mm SL) and 'Large' (≥ 100 mm SL). Area is used as the sampling unit.

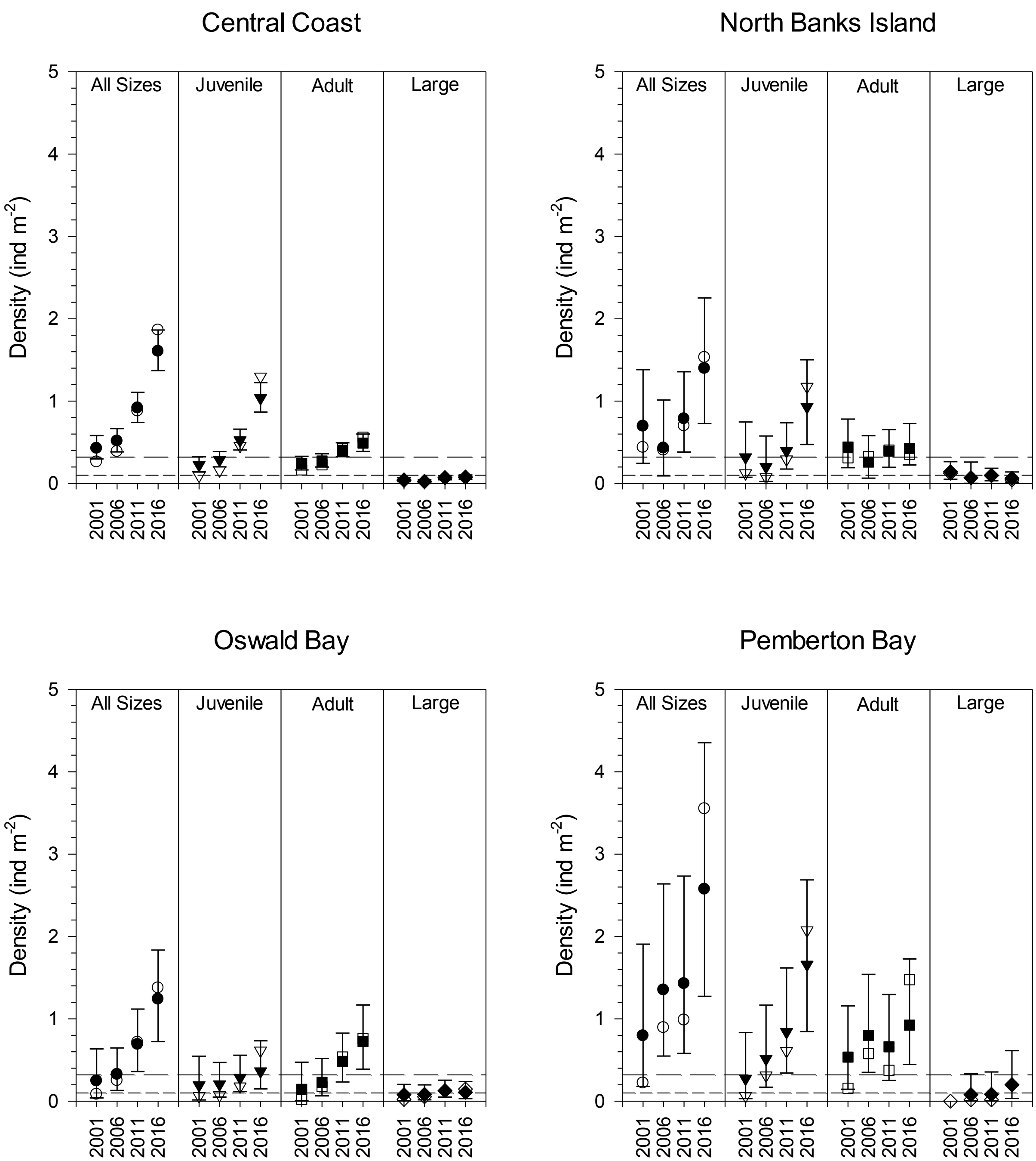


Figure 19. Estimated density of Northern Abalone at index sites for the entire Central Coast Region, as well as for each individual Area for the years 2001-2016. Estimated densities are given for the size classes: 'All' (≥ 20 mm SL), 'Juvenile' (≥ 20 mm and < 70 mm SL), 'Adult' (≥ 70 mm SL) and 'Large' (≥ 100 mm SL). Values are mean estimated density ± 95% credible interval (filled symbols). The long dashed line indicates 0.32 ind m^{-2} (the Population and Distribution Objective for Adult Abalone) and the short dashed line indicates 0.1 ind m^{-2} (the Population and Distribution Objective for Large Abalone). Open symbols are the observed values for reference.

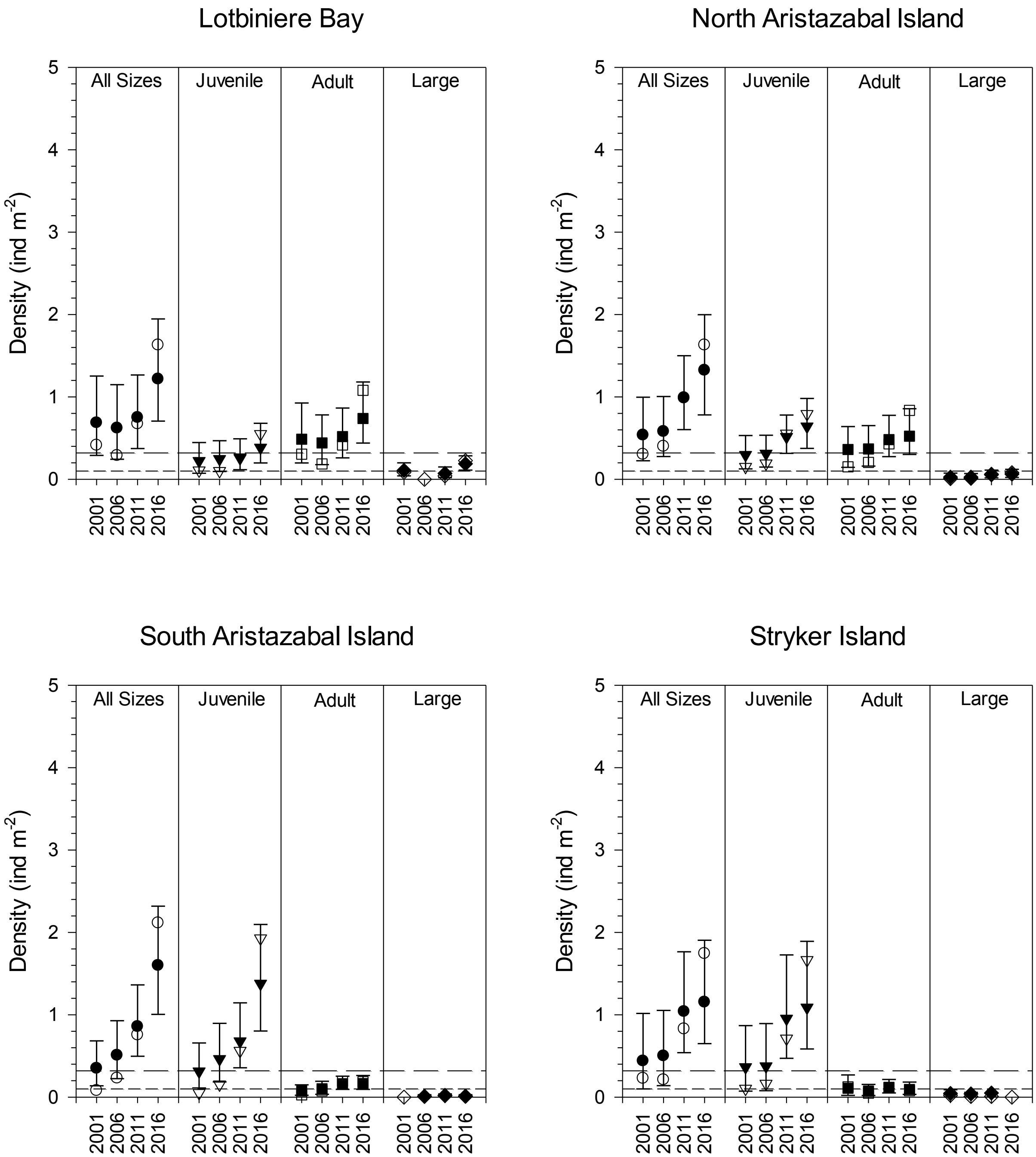


Figure 19. Con't.

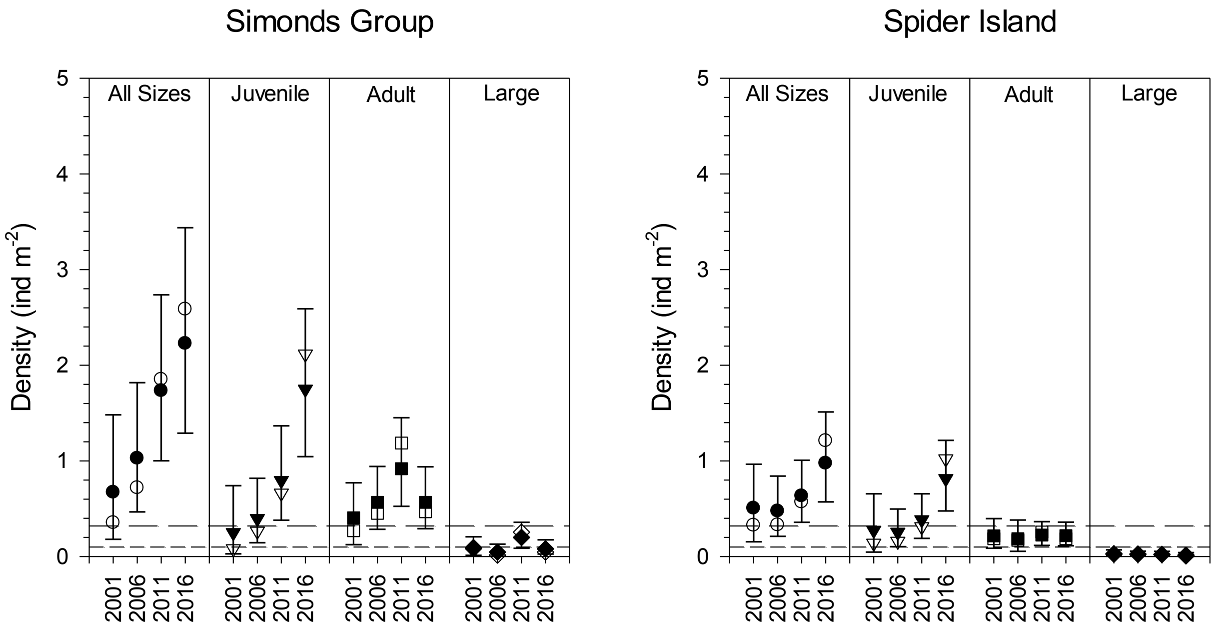


Figure 19. Con't.

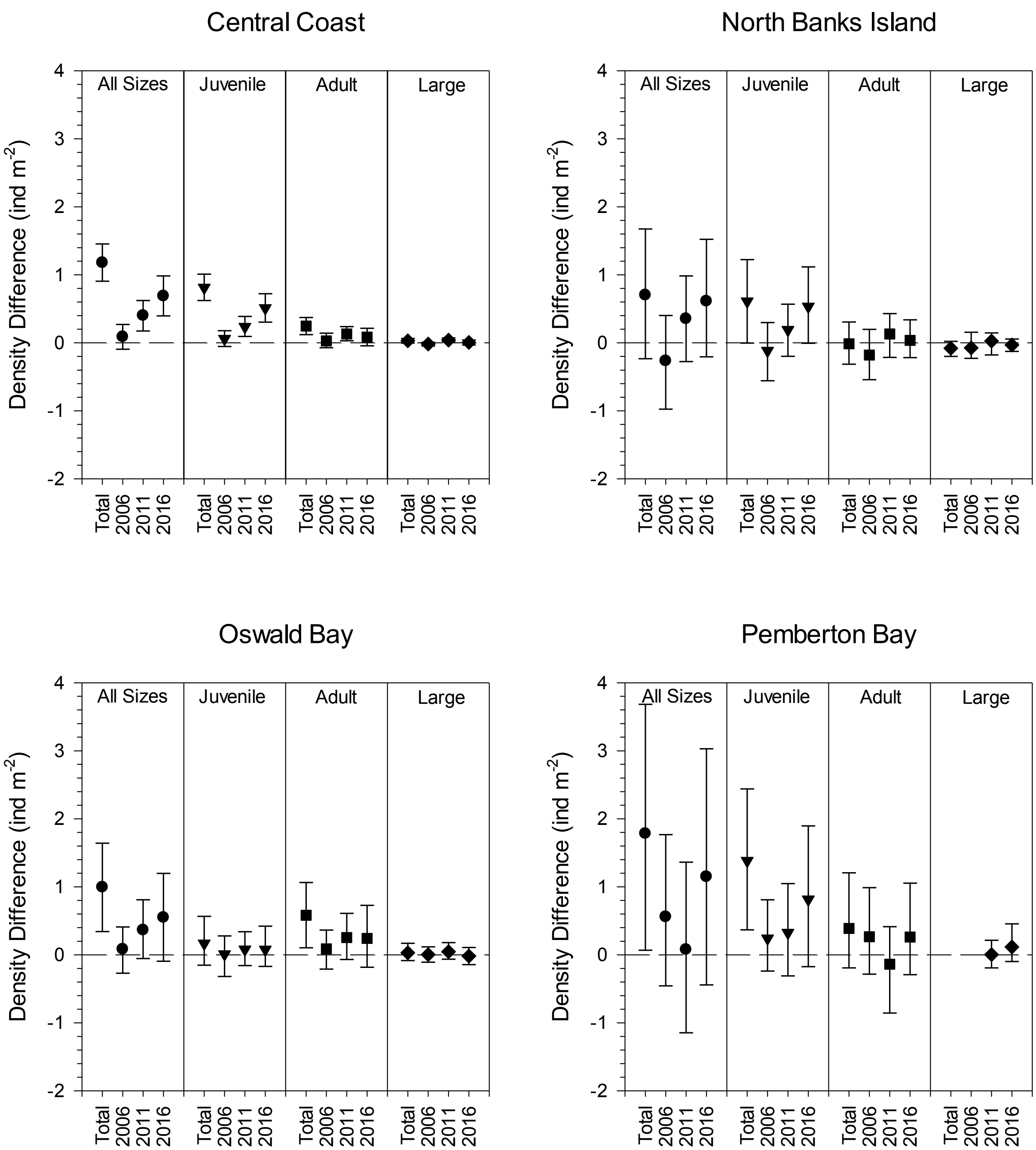


Figure 20. Estimated density difference of Northern Abalone at index sites for the entire Central Coast Region, as well as for each individual Area. Estimated density difference is shown for the size classes: 'All' (≥ 20 mm SL), 'Juvenile' (≥ 20 mm and < 70 mm SL), 'Adult' (≥ 70 mm SL) and 'Large' (≥ 100 mm SL). Values are mean estimated density difference ± 95% credible interval between a given survey year and the survey year prior. 'Total' is the estimated density difference between 2016 and 2001. Credible intervals that overlap the dashed line indicate no change in density.

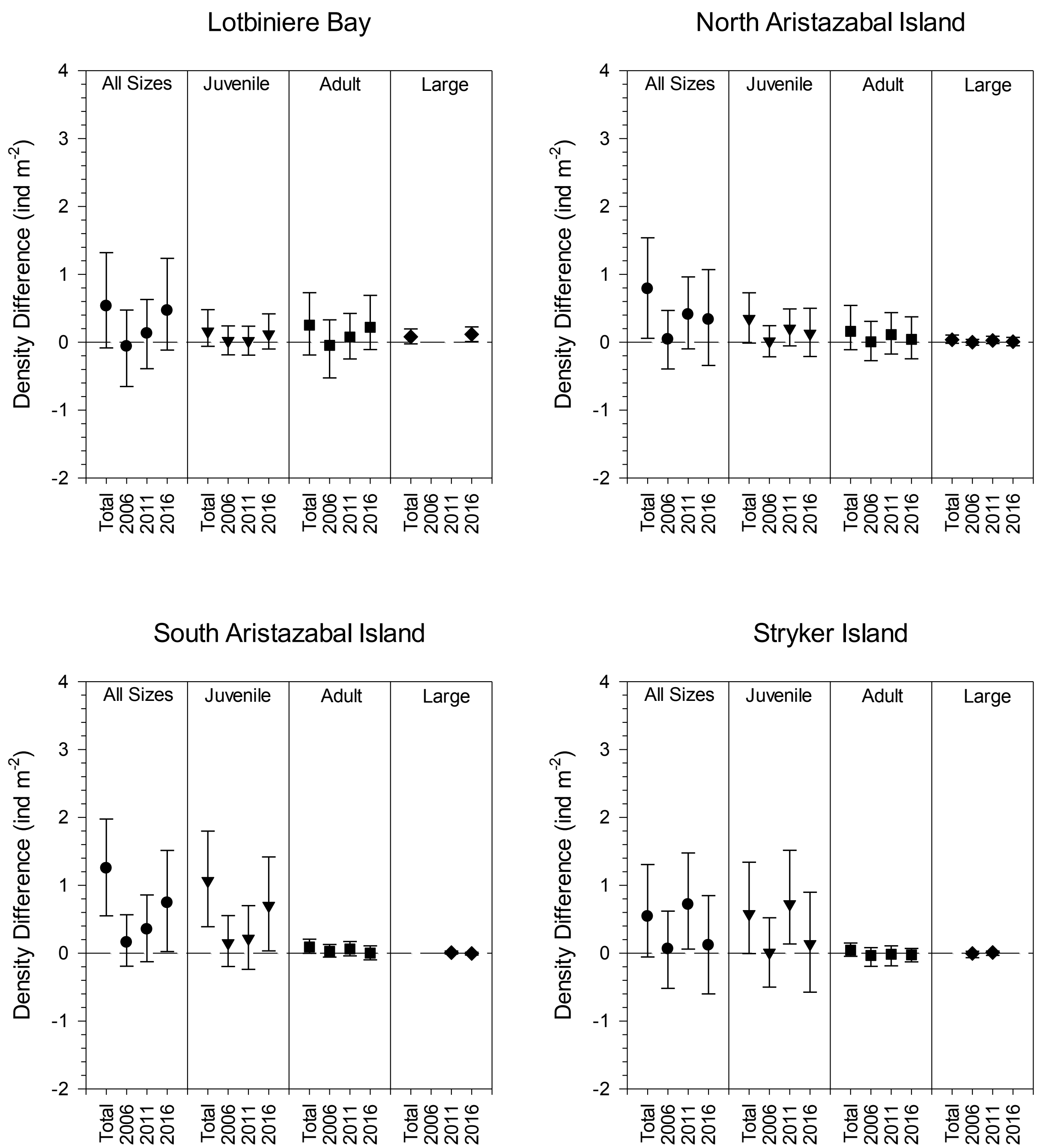
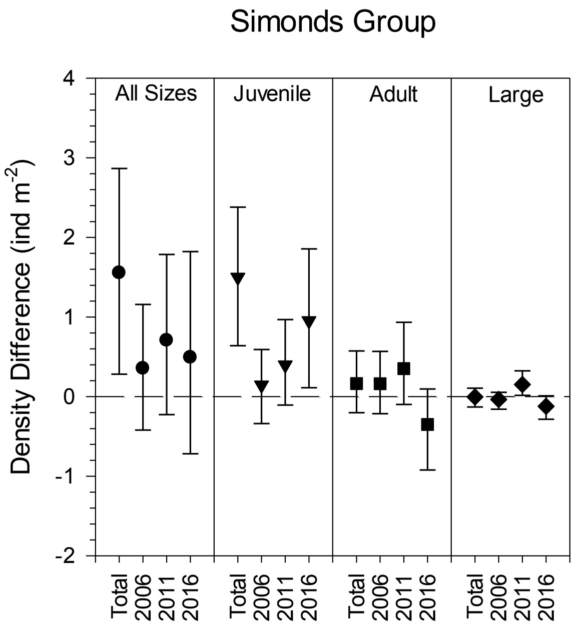


Figure 20. Con’t.



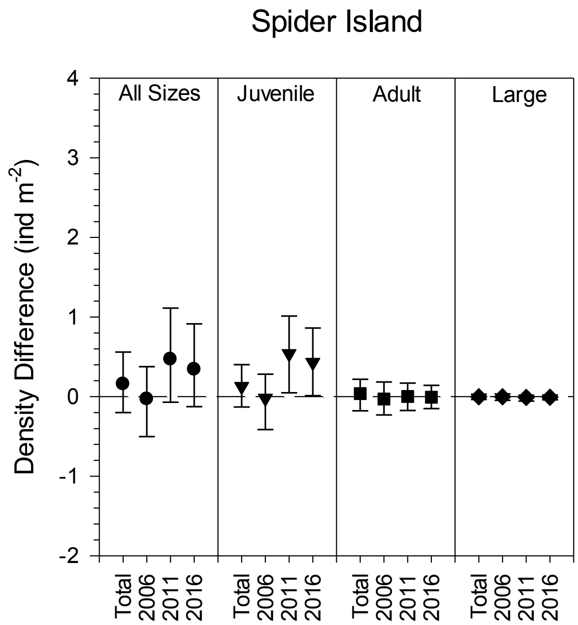


Figure 20. Con't.

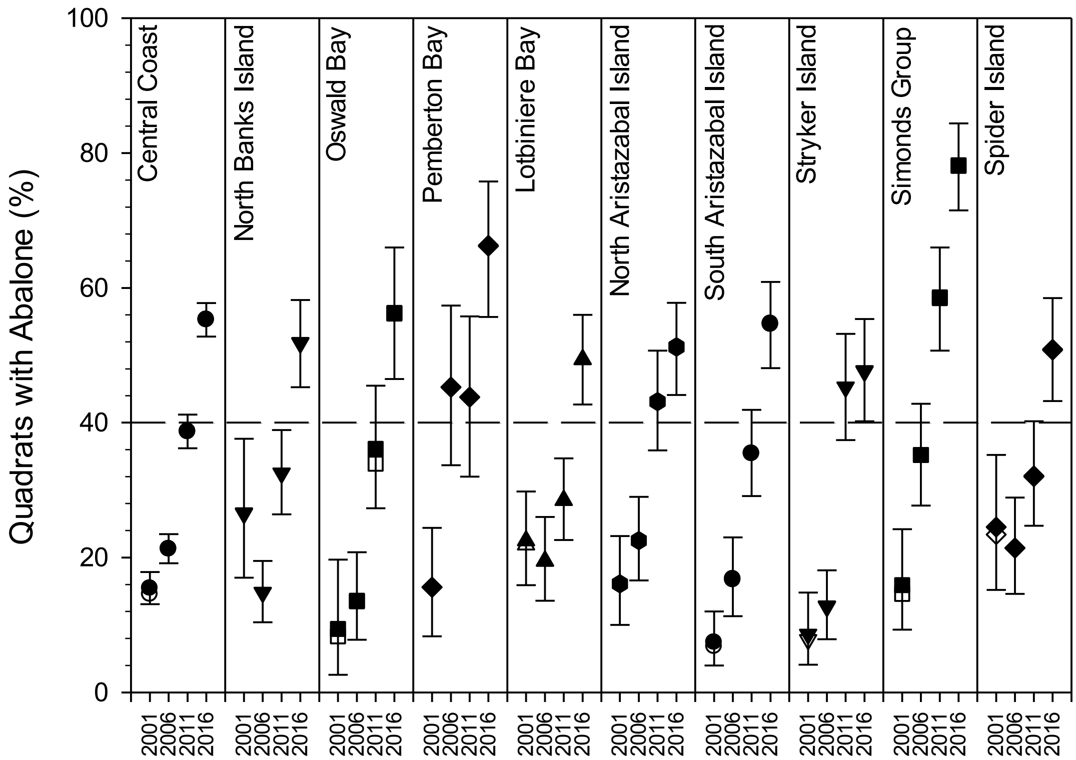


Figure 21. The estimated percentage of quadrats with Northern Abalone for the entire Central Coast Region, as well as for each individual Area. Values are the mean estimated percentage of quadrats ± 95% credible interval (filled symbols) and the observed percentage of quadrats (open symbols) with at least one Northern Abalone. The dashed line is at 40%, the Population and Distribution Objective for the percentage of quadrats with Abalone.

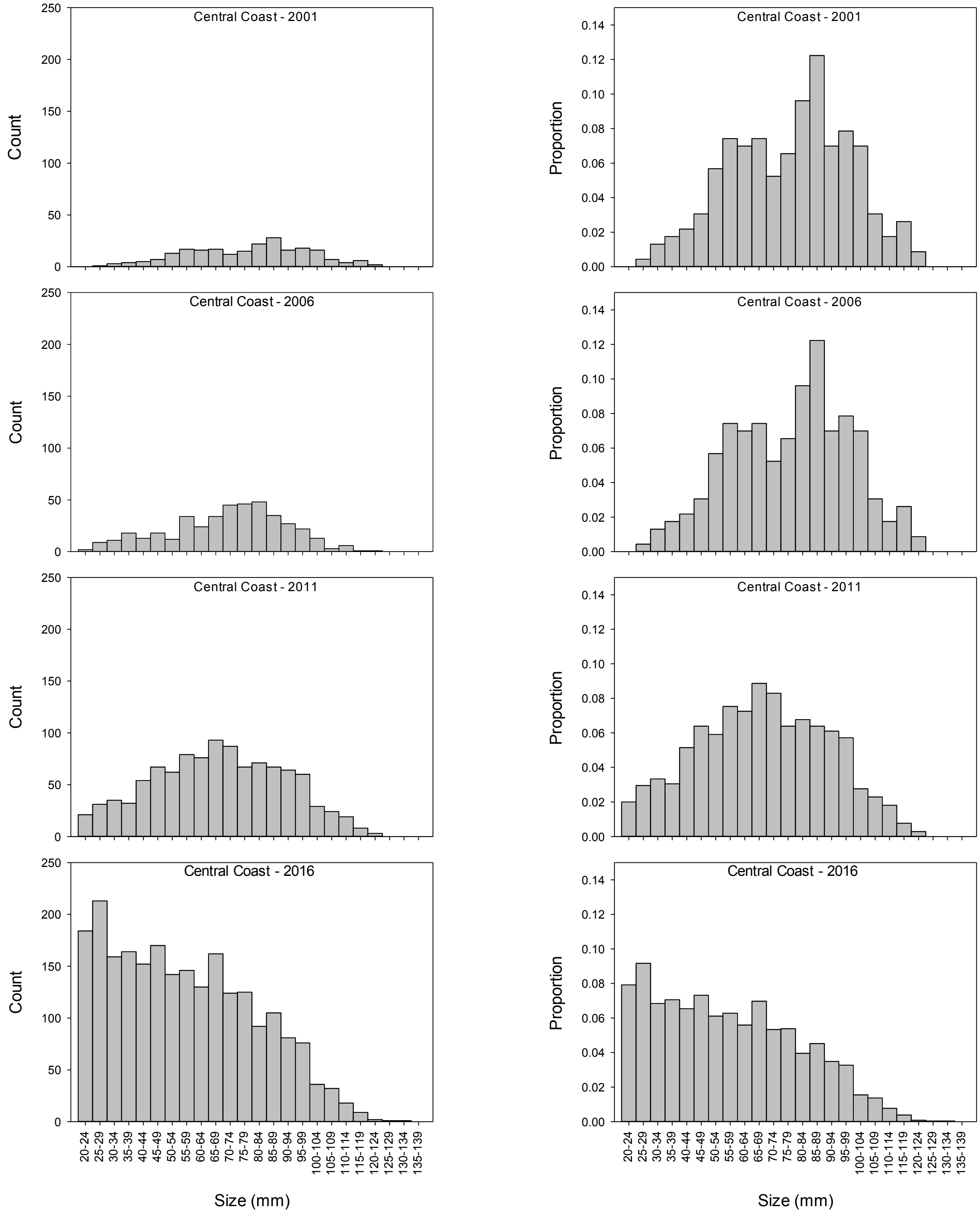


Figure 22. Size frequency histograms of Northern Abalone between 20 and 139 mm shell length, measured during index site surveys on the Central Coast from 2001 to 2016. The absolute number of Abalone measured and the relative proportion are shown for each 5-mm size bin. Data are hedged at 20 mm due to the cryptic nature and difficulty in detecting Abalone smaller than this size. No Abalone greater than 139 mm were observed.

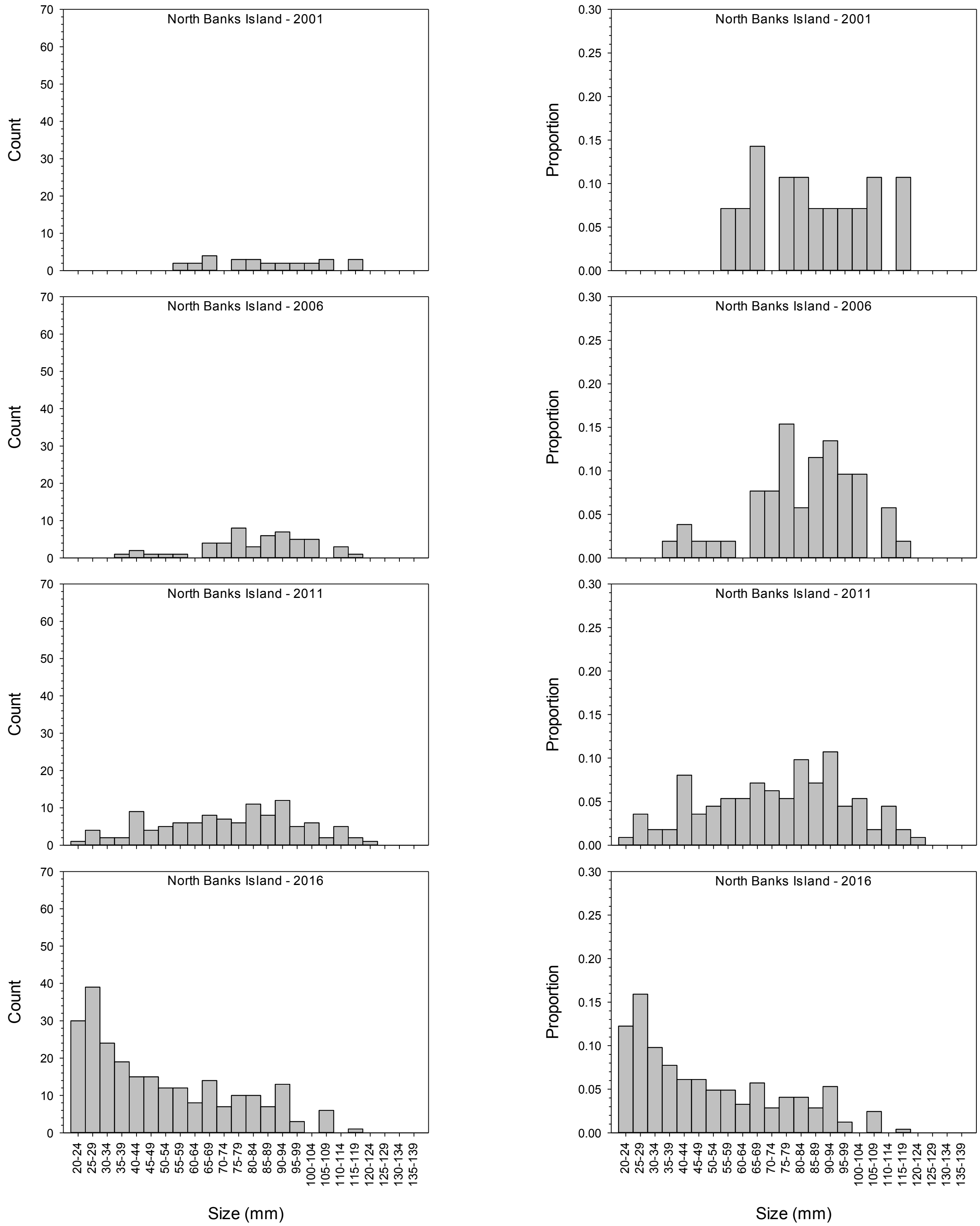


Figure 23. Size frequency histograms of Northern Abalone between 20 and 139 mm shell length, measured during index site surveys for each Area on the Central Coast from 2001 to 2016. The absolute number of Abalone measured and the relative proportion are shown for each 5-mm size bin. Data are hedged at 20 mm due to the cryptic nature and difficulty in detecting Abalone smaller than this size. No Abalone greater than 139 mm were observed.

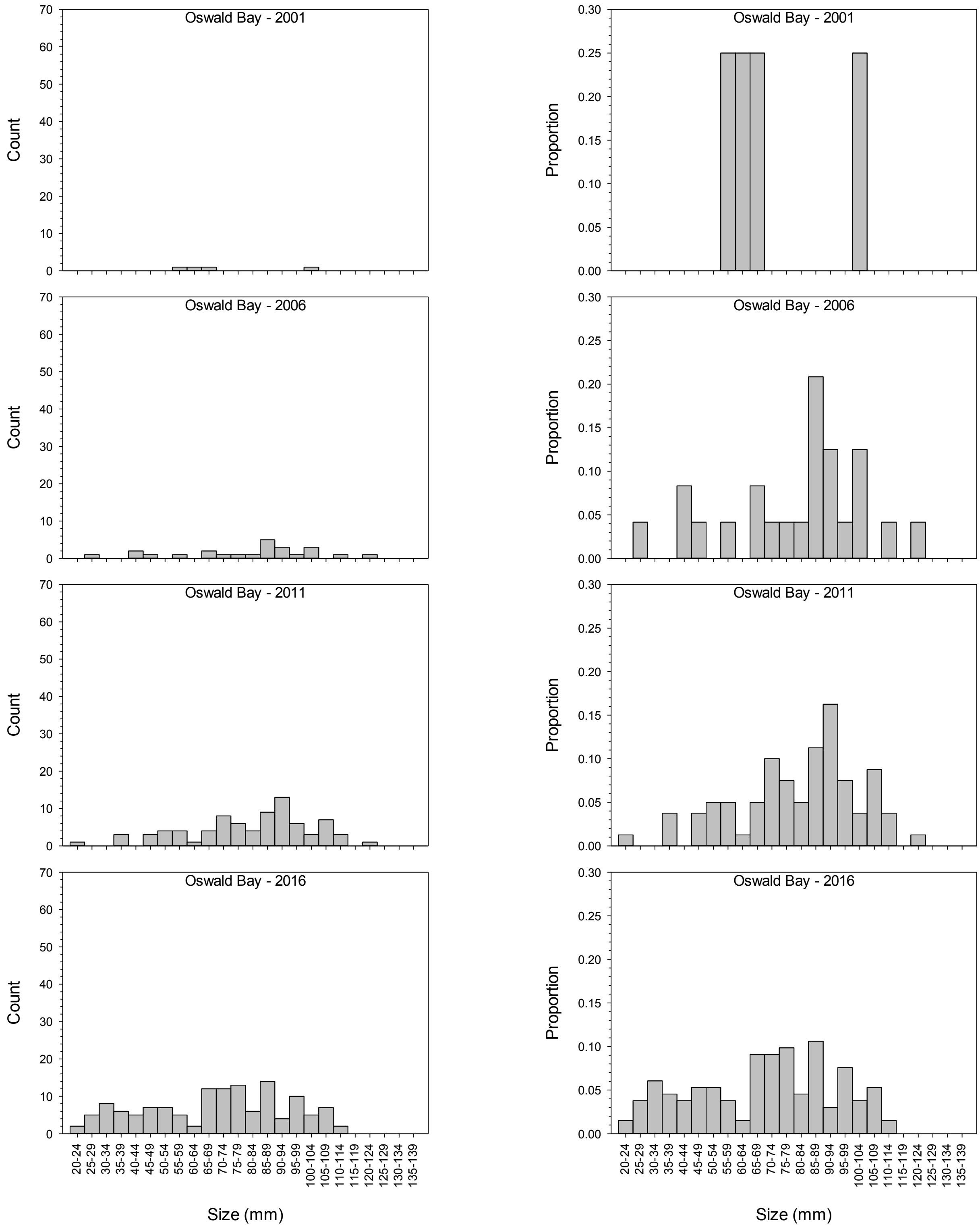


Figure 23. Con't.

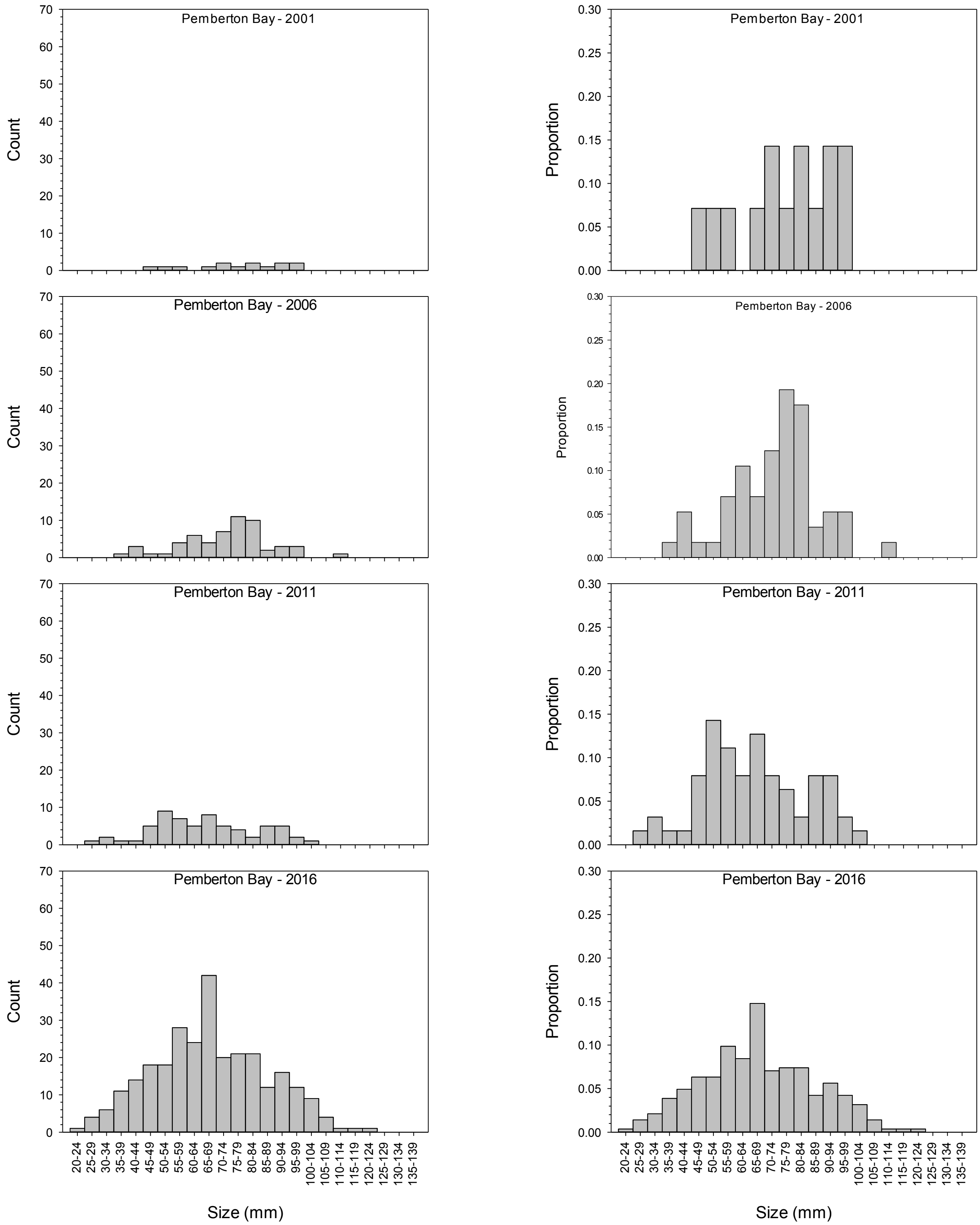


Figure 23. Con't.

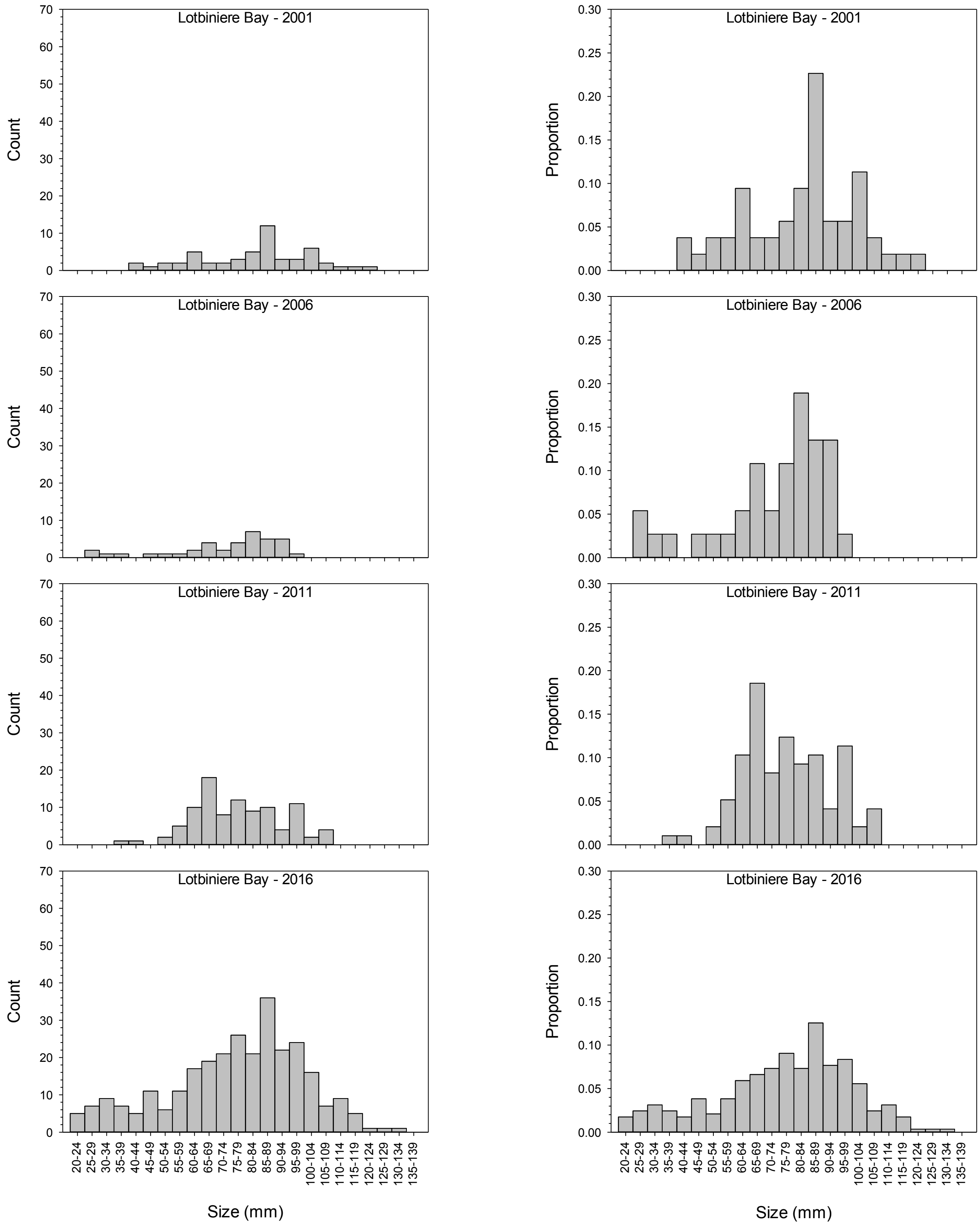


Figure 23. Con't.

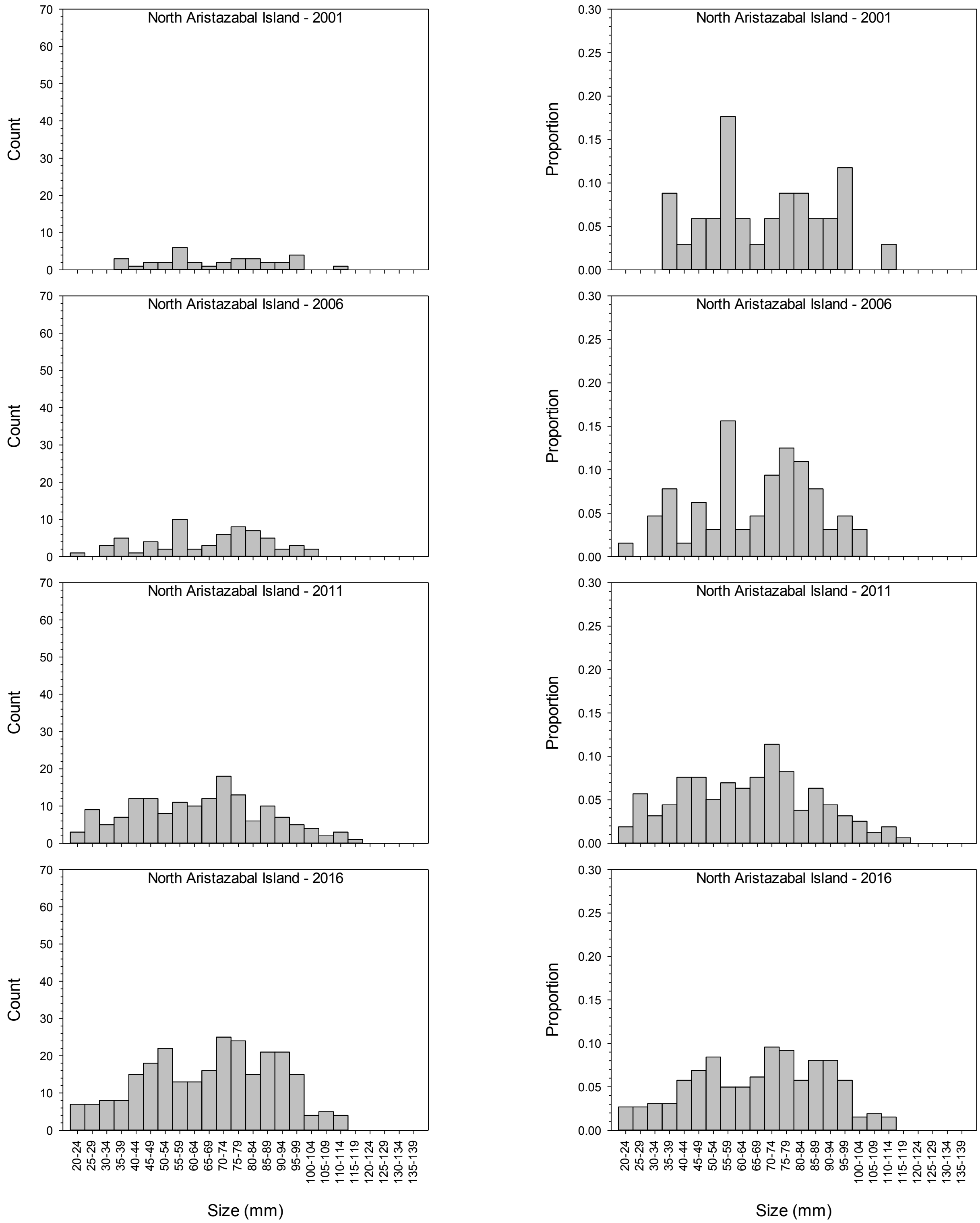


Figure 23. Con't.

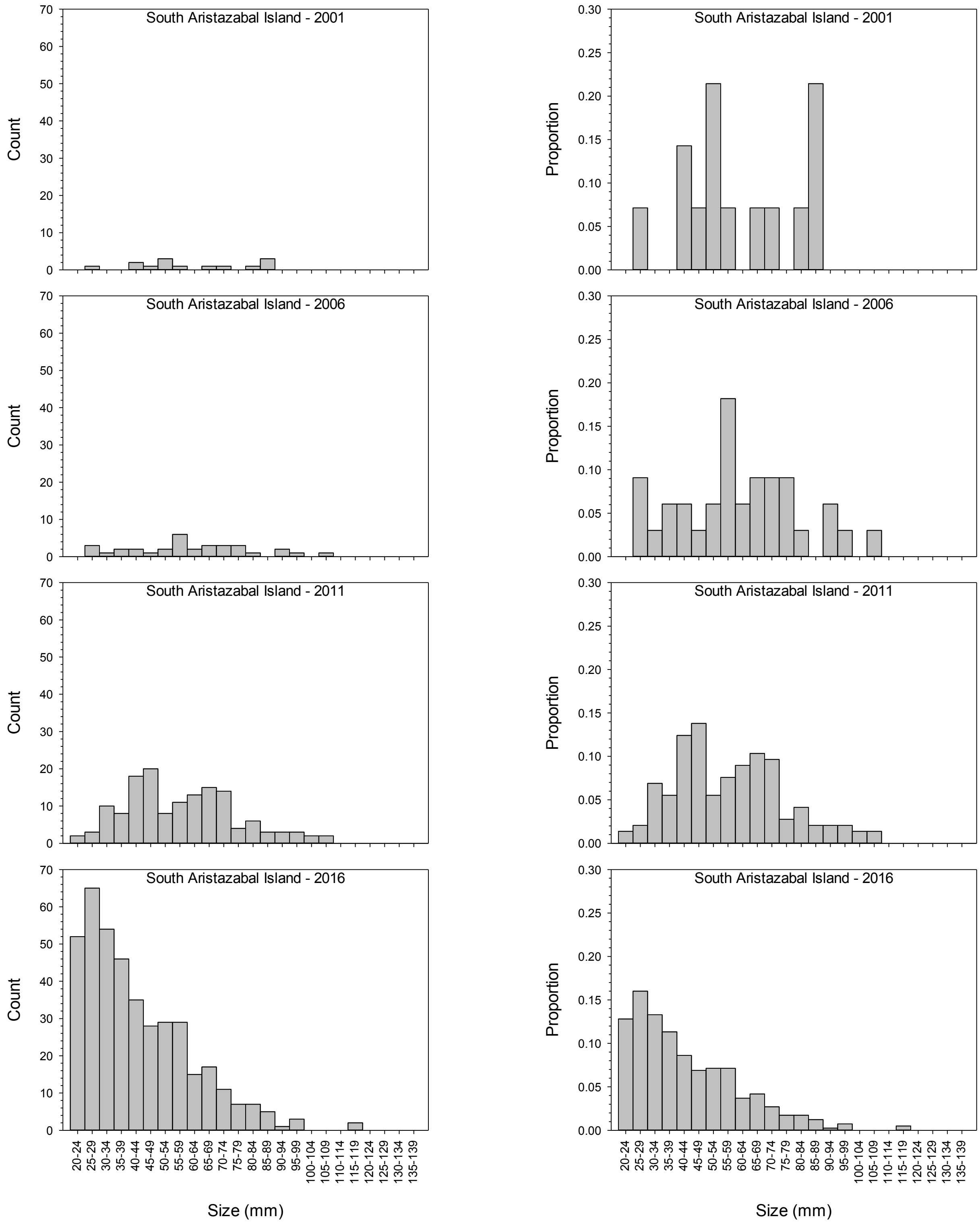


Figure 23. Con't.

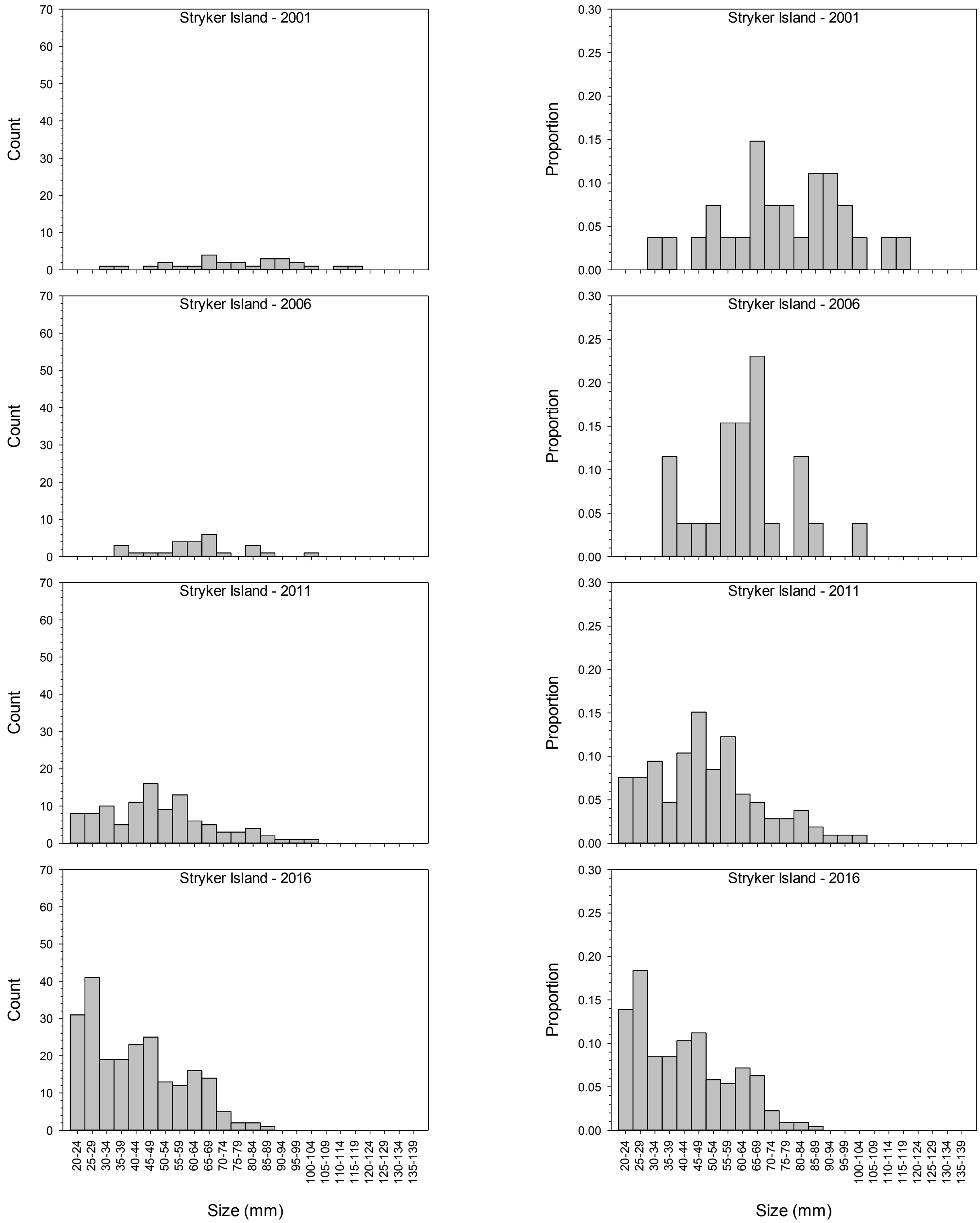


Figure 23. Con't.

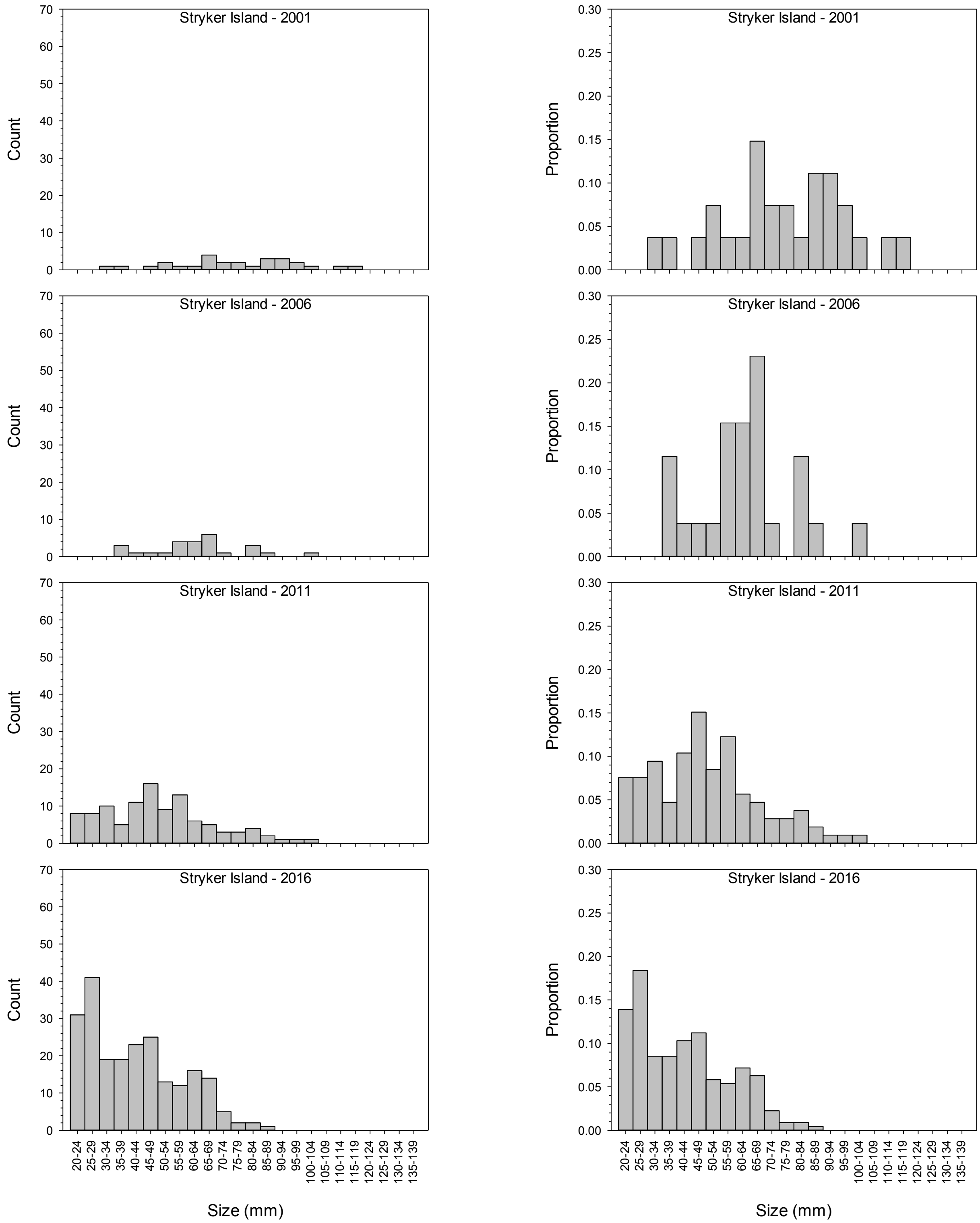


Figure 23. Con’t.

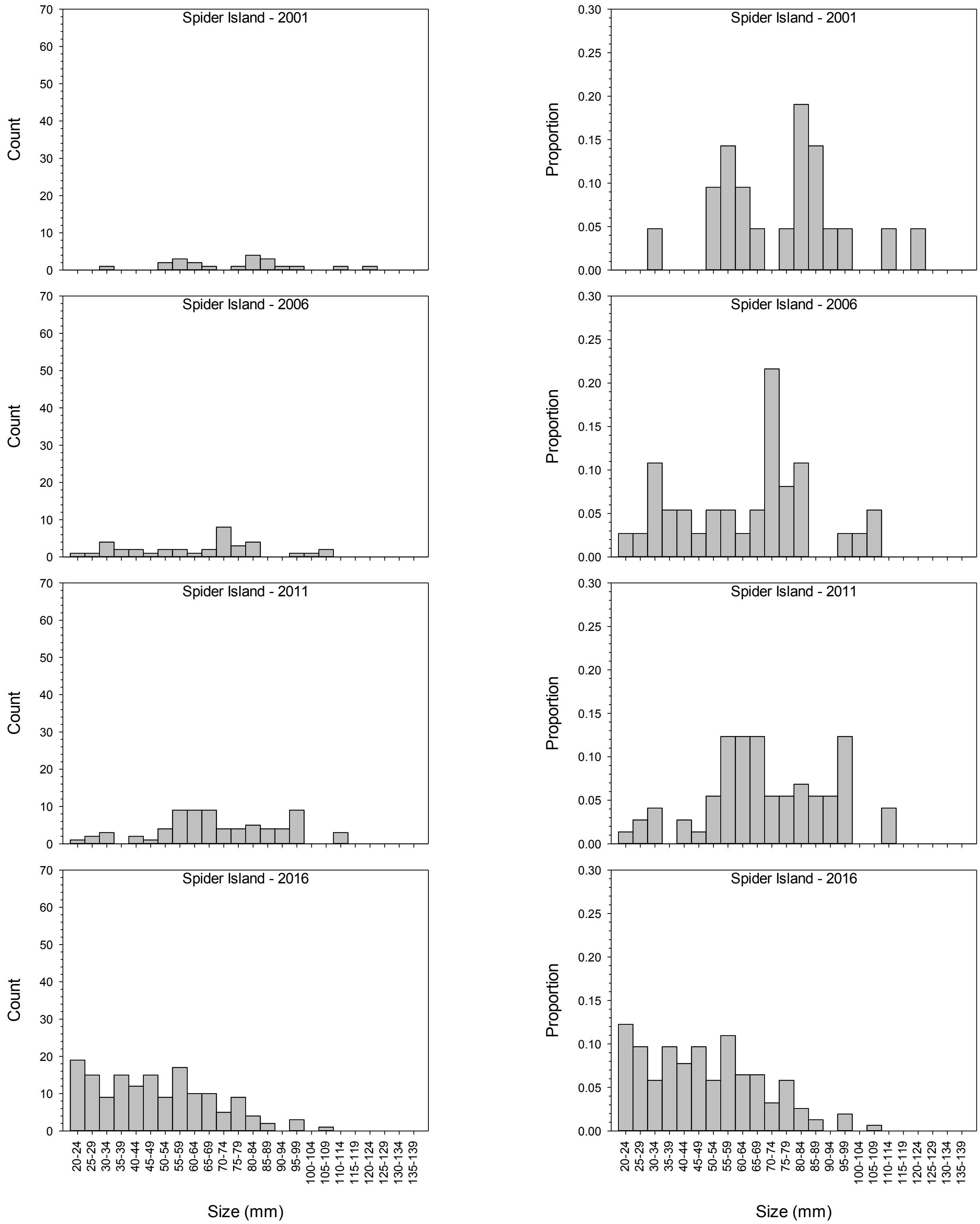


Figure 23. Con't.

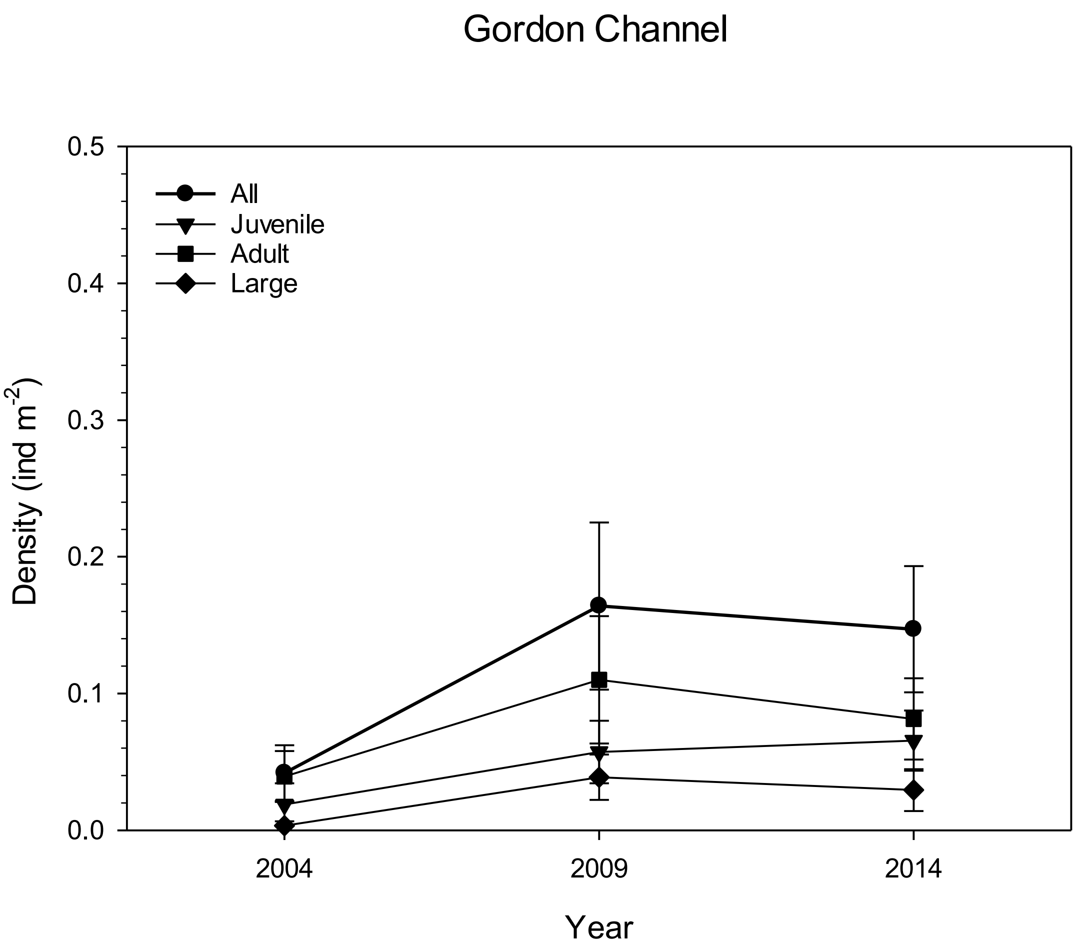


Figure 24. Summary density data for Northern Abalone index site surveys carried out in the Gordon Channel Area of the Queen Charlotte Strait Region, 2004-2014. Values are mean observed density (individuals m^{-2}) ± SE for the size classes: ‘All’, ‘Juvenile’ (< 70 mm SL), ‘Adult’ (≥ 70 mm SL) and ‘Large’ (≥ 100 mm SL). Site is used as the sampling unit.

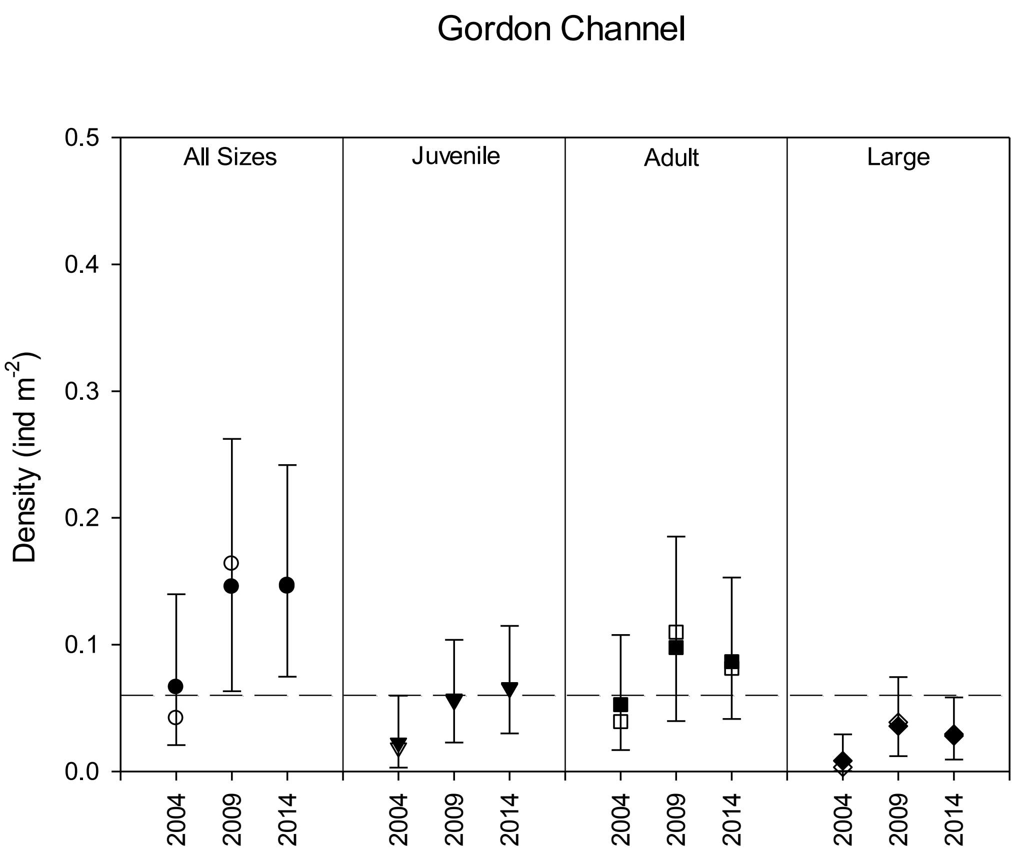


Figure 25. Estimated density of Northern Abalone at index sites in the Gordon Channel Area of the Queen Charlotte Strait Region, 2004-2014. Estimated densities are given for the size classes: 'All', 'Juvenile' (< 70 mm SL), 'Adult' (≥ 70 mm SL) and 'Large' (≥ 100 mm SL). Values are mean estimated density ± 95% credible interval (filled symbols). The long dashed line indicates 0.06 ind m^{-2} (the Population and Distribution Objective for the total density of Abalone). Open symbols are the observed values for reference.

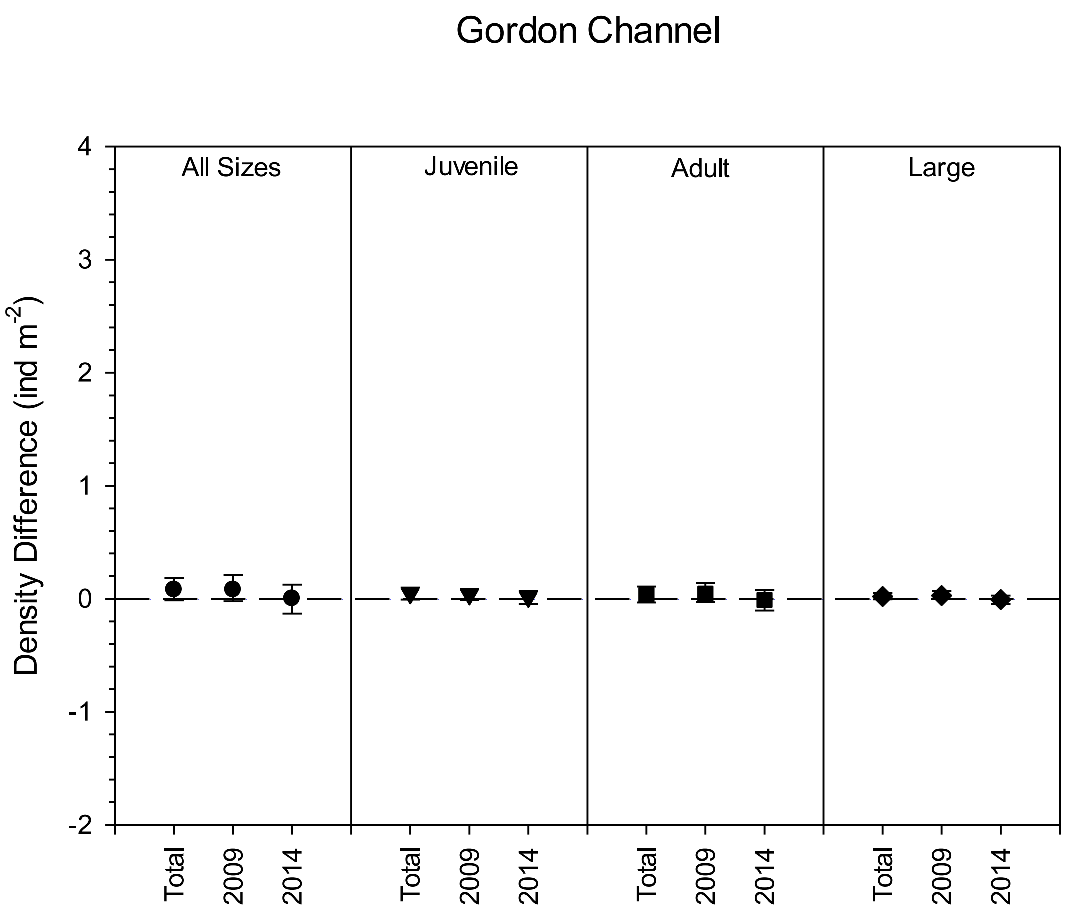


Figure 26. Estimated density difference of Northern Abalone at index sites in the Gordon Channel Area of the Queen Charlotte Strait Region. Estimated density difference is shown for the size classes: ‘All’, ‘Juvenile’ (< 70 mm SL), ‘Adult’ (≥ 70 mm SL) and ‘Large’ (≥ 100 mm SL). Values are mean estimated density difference ± 95% credible interval between a given survey year and the survey year prior. ‘Total’ is the estimated density difference between 2014 and 2004. Credible intervals that overlap the dashed line indicate no change in density.

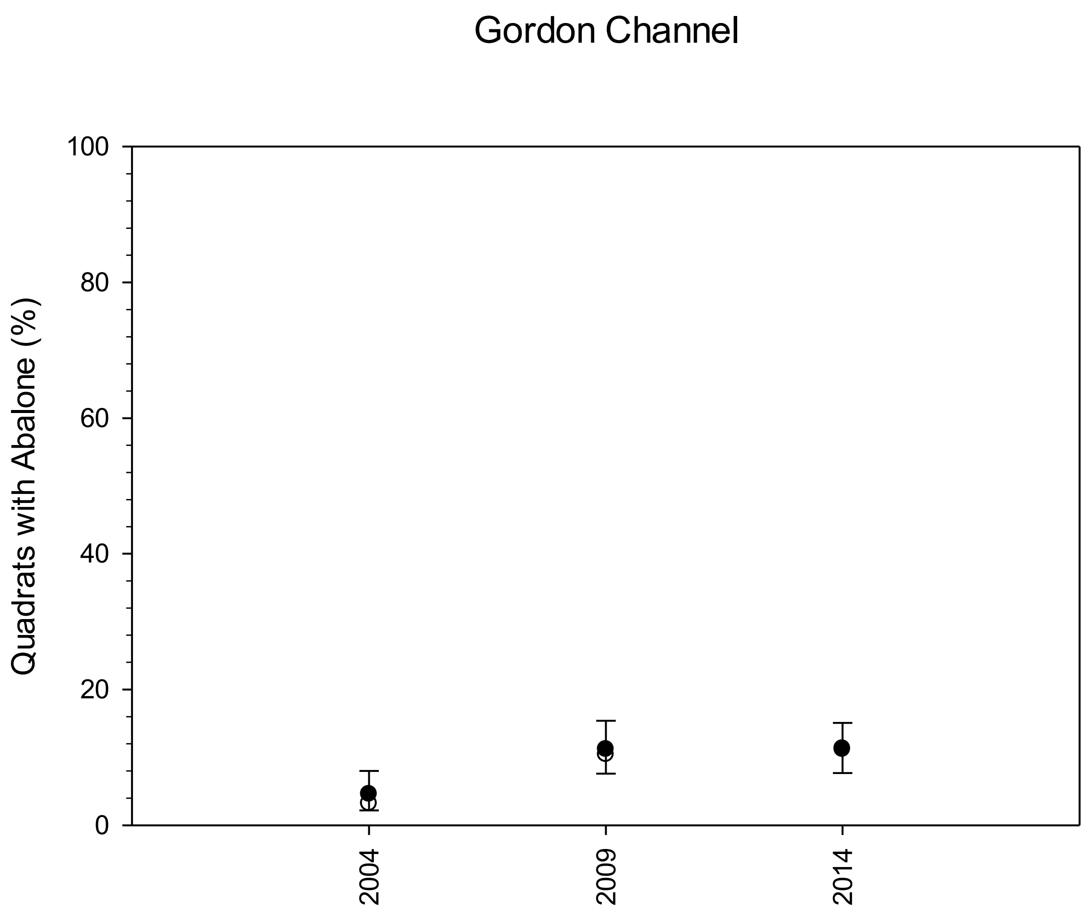


Figure 27. The estimated percentage of quadrats with Northern Abalone for the Gordon Channel Area of the Queen Charlotte Strait Region. Values are the mean estimated percentage of quadrats ± 95% credible interval (filled symbols) and the observed percentage of quadrats (open symbols) with at least one Northern Abalone.

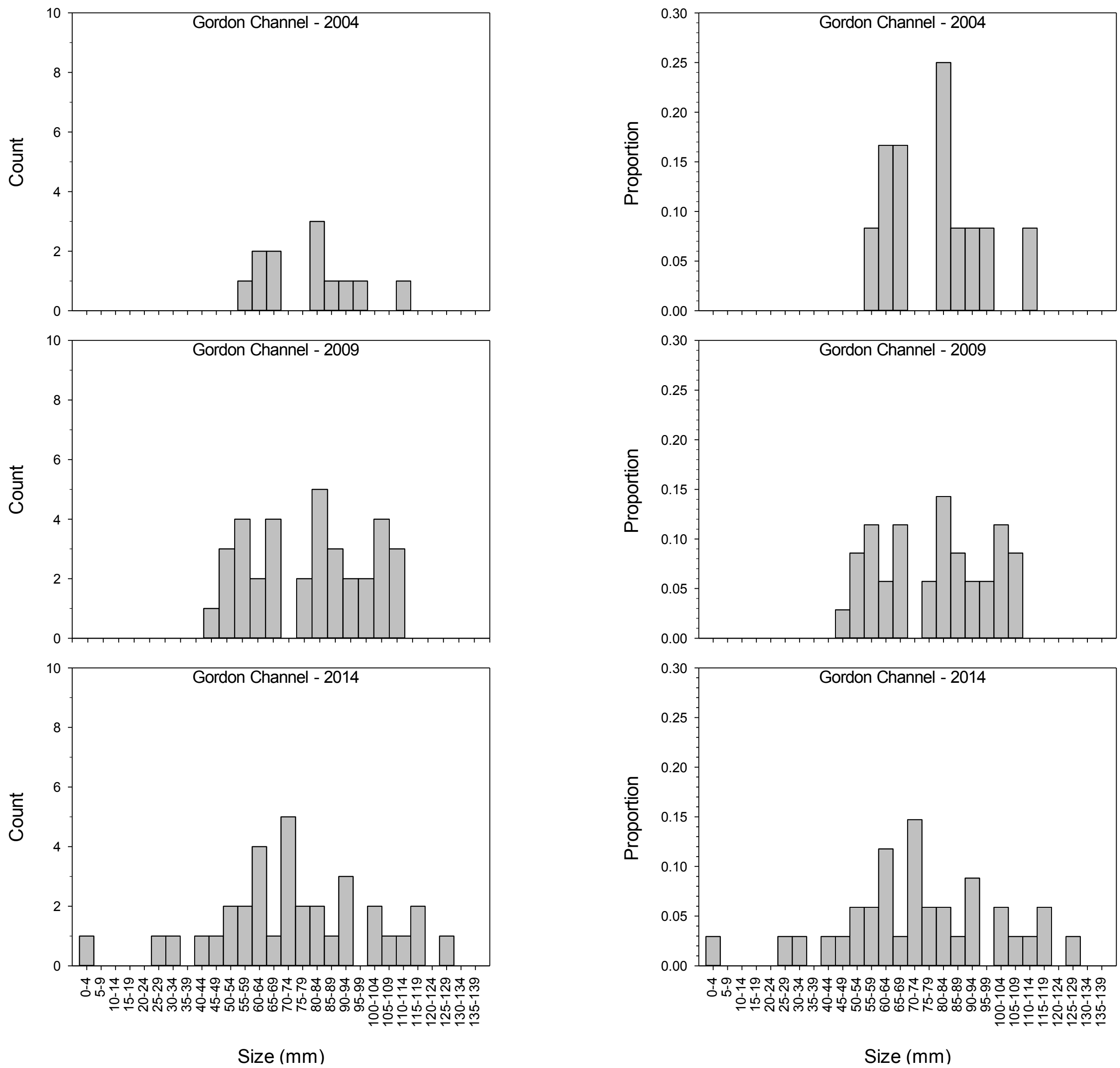


Figure 28. Size frequency histograms of Northern Abalone measured during index site surveys in the Gordon Channel Area of the Queen Charlotte Strait Region 2004-2014. The absolute number of Abalone measured and the relative proportion are shown for each 5-mm size bin.

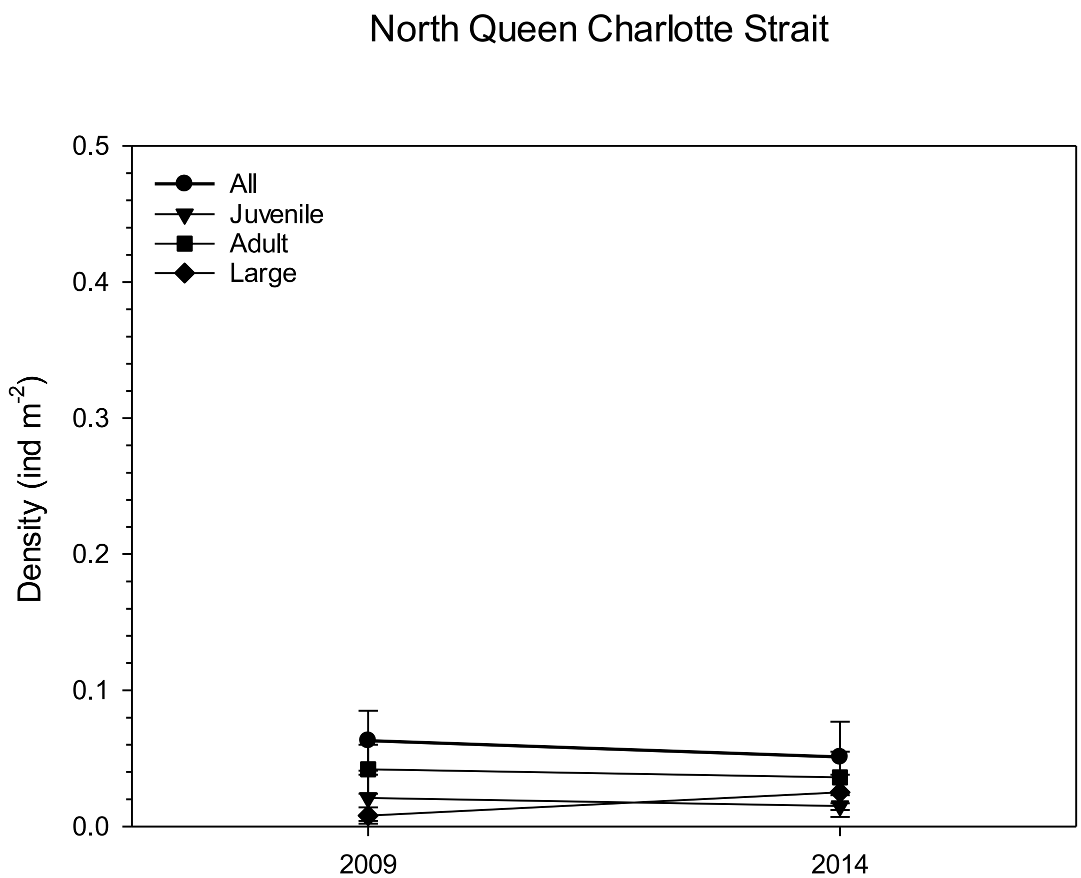


Figure 29. Summary density data for Northern Abalone index site surveys carried out in the North Queen Charlotte Strait Area of the Queen Charlotte Strait Region in 2009 and 2014. Values are mean observed density (individuals m^{-2}) ± SE for the size classes: 'All', 'Juvenile' (< 70 mm SL), 'Adult' (≥ 70 mm SL) and 'Large' (≥ 100 mm SL). Site is used as the sampling unit.

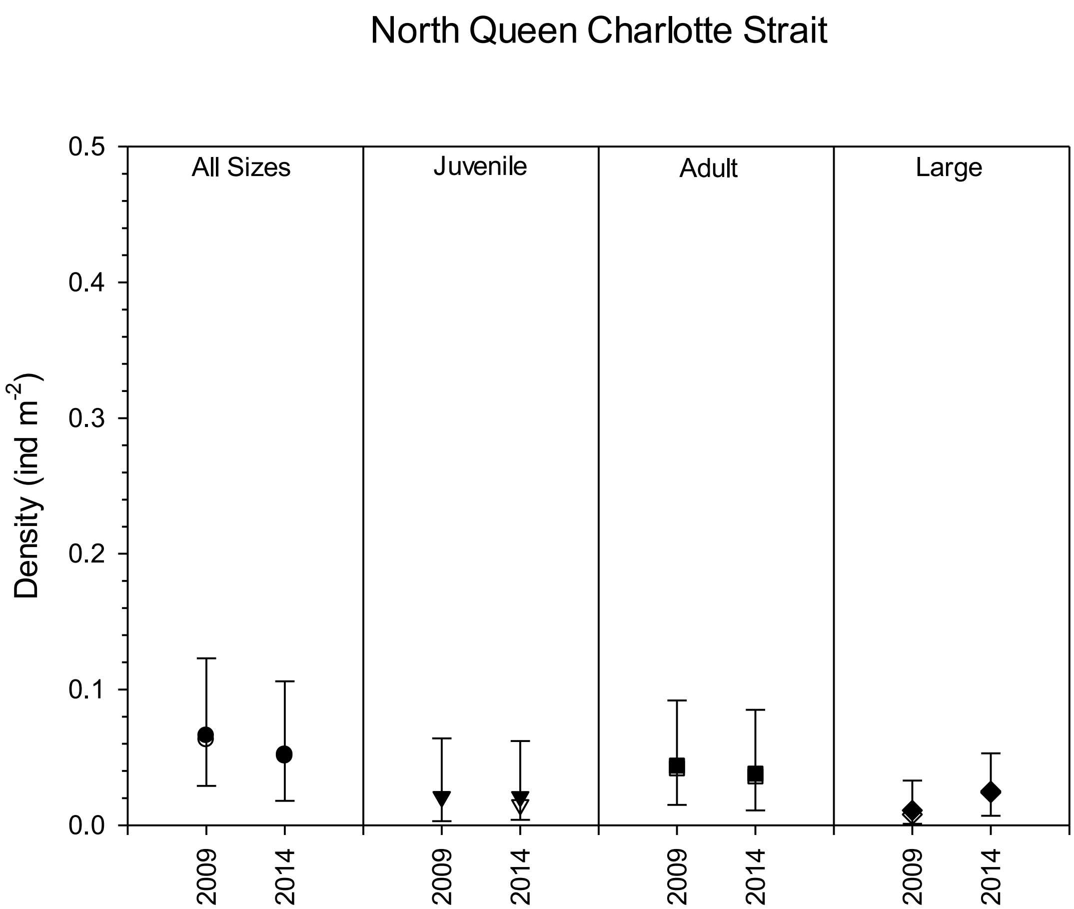


Figure 30. Estimated density of Northern Abalone at index sites in the North Queen Charlotte Strait Area of the Queen Charlotte Strait Region in 2009 and 2014. Estimated densities are given for the size classes: 'All', 'Juvenile' (< 70 mm SL), 'Adult' (≥ 70 mm SL) and 'Large' (≥ 100 mm SL). Values are mean estimated density ± 95% credible interval (filled symbols). Open symbols are the observed values for reference.

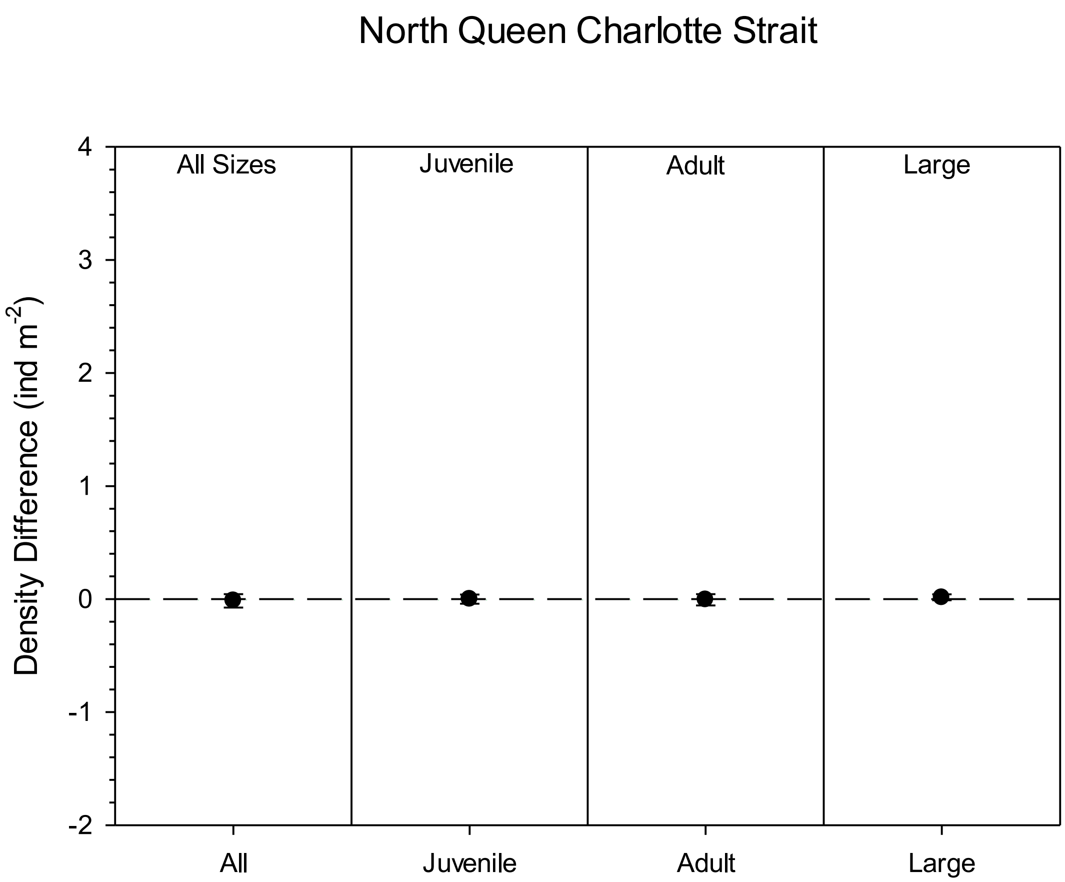


Figure 31. Estimated density difference of Northern Abalone at index sites in the North Queen Charlotte Strait Area of the Queen Charlotte Strait Region. Estimated density difference is shown for the size classes: ‘All’, ‘Juvenile’ (< 70 mm SL), ‘Adult’ (≥ 70 mm SL) and ‘Large’ (≥ 100 mm SL). Values are mean estimated density difference ± 95% credible interval between 2009 and 2014. Credible intervals that overlap the dashed line indicate no change in density.

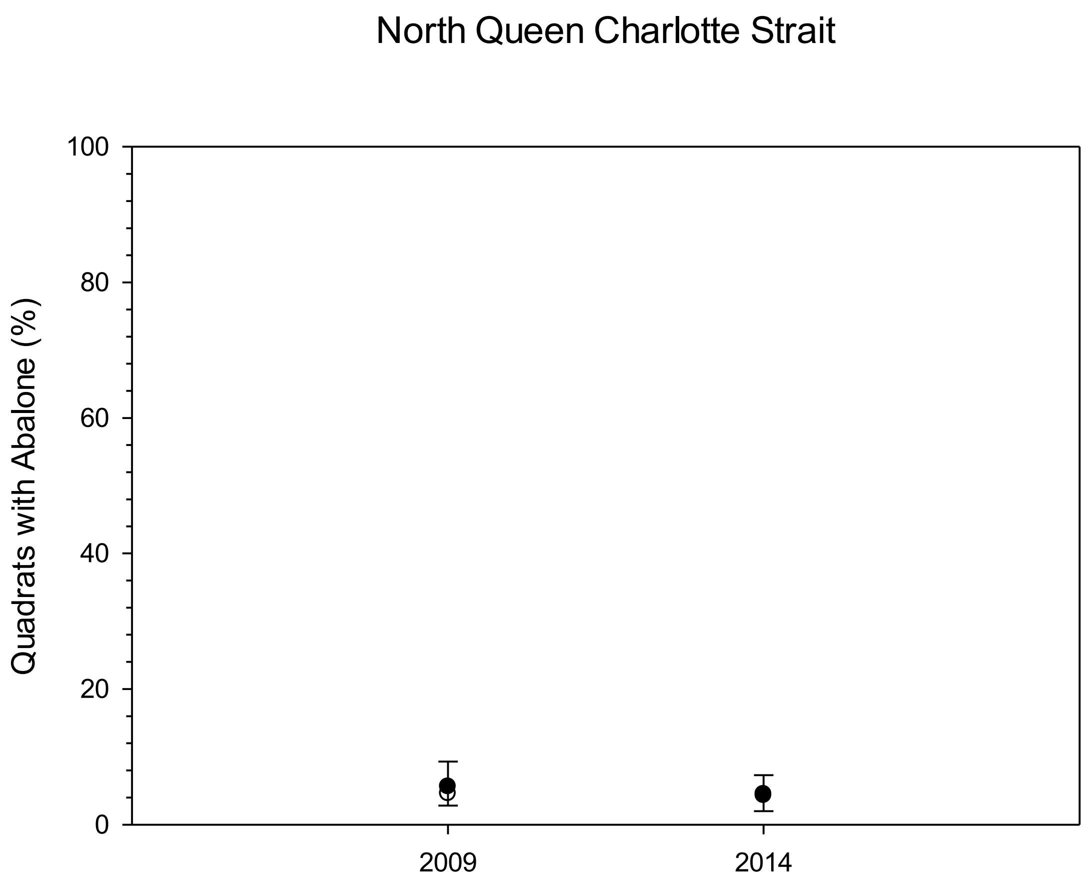


Figure 32. The estimated percentage of quadrats with Northern Abalone for the North Queen Charlotte Strait Area of the Queen Charlotte Strait Region. Values are the mean estimated percentage of quadrats ± 95% credible interval (filled symbols) and the observed percentage of quadrats (open symbols) with at least one Northern Abalone.

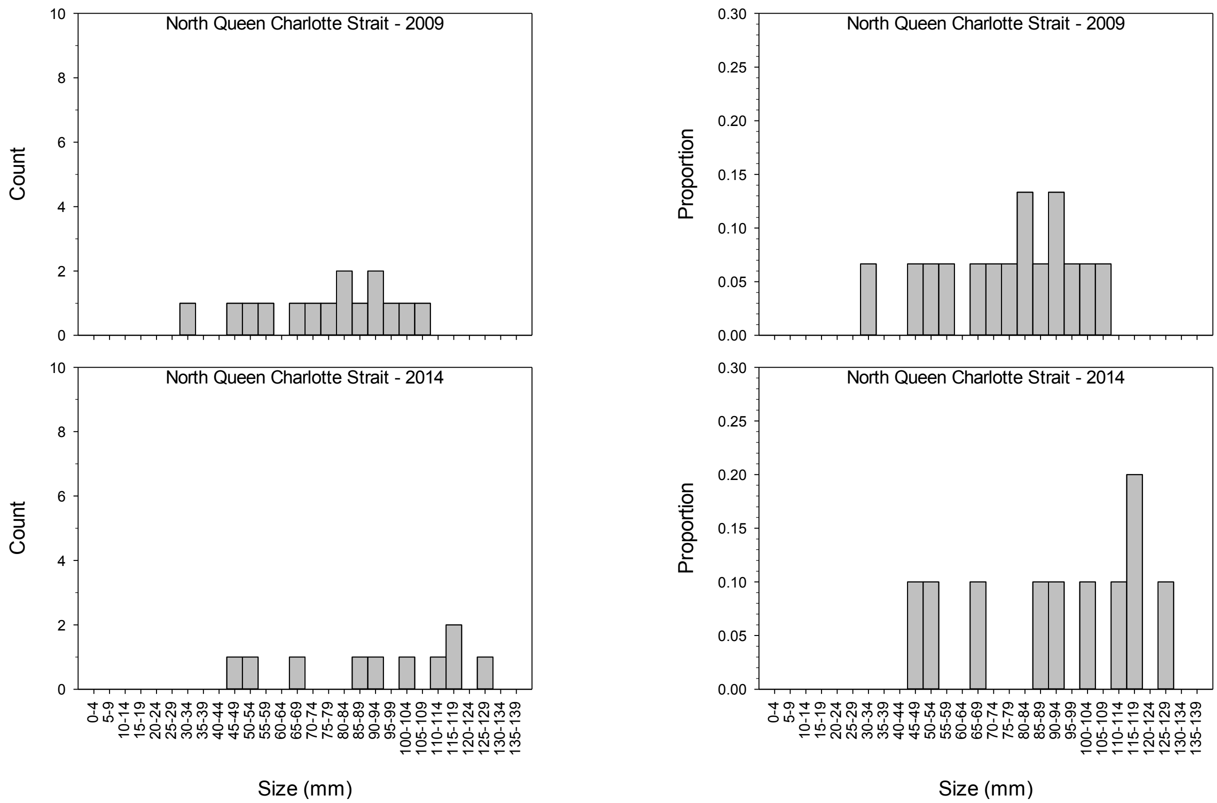


Figure 33. Size frequency histograms of Northern Abalone measured during index site surveys in the North Queen Charlotte Strait Area of the Queen Charlotte Strait Region 2004-2014. The absolute number of Abalone measured and the relative proportion are shown for each 5-mm size bin.

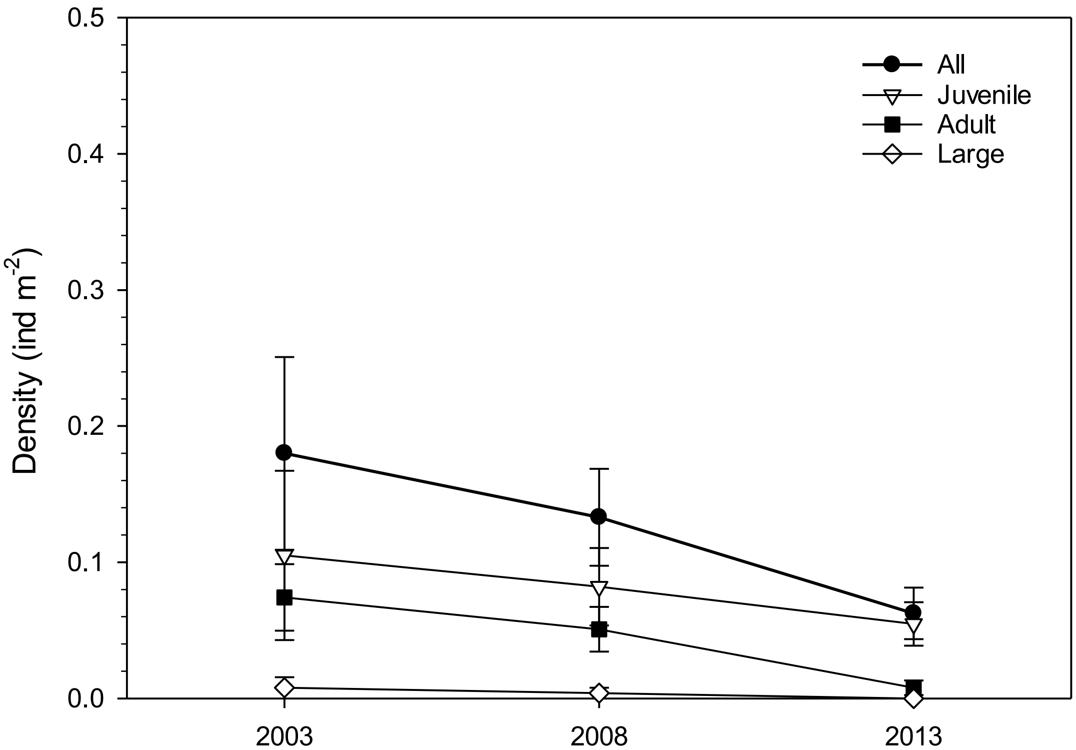


Figure 34. Summary of density data at repeated sites in the West Coast Vancouver Island Region from Northern Abalone index site surveys 2003 to 2013. See Appendix 1 for a list of repeated sites. Values are mean density (individuals m^{-2}) ± SE for the size classes: 'All', 'Juvenile' (< 70 mm SL), 'Adult' (≥ 70 mm SL), and 'Large' (≥ 100 mm). Site is used as the sampling unit for standard error calculations.

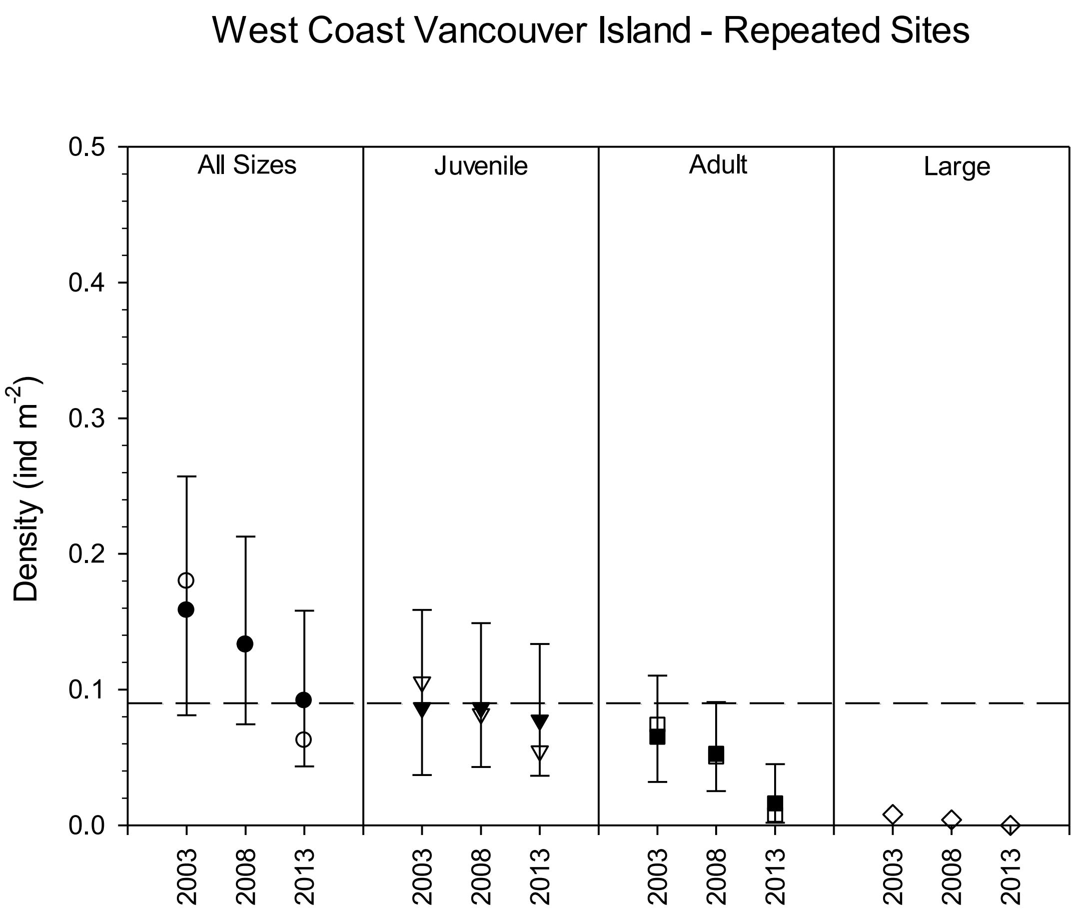


Figure 35. Estimated density of Northern Abalone at repeated index sites in the West Coast Vancouver Island Region, 2003-2013. Estimated densities are given for the size classes: ‘All’ (≥ 20 mm), ‘Juvenile’ (≥ 20 mm and < 70 mm SL), ‘Adult’ (≥ 70 mm SL) and ‘Large’ (≥ 100 mm SL). Values are mean estimated density ± 95% credible interval (filled symbols). The long dashed line indicates 0.09 ind m^{-2} (the Population and Distribution Objective for the total density of Abalone). Open symbols are the observed values for reference.

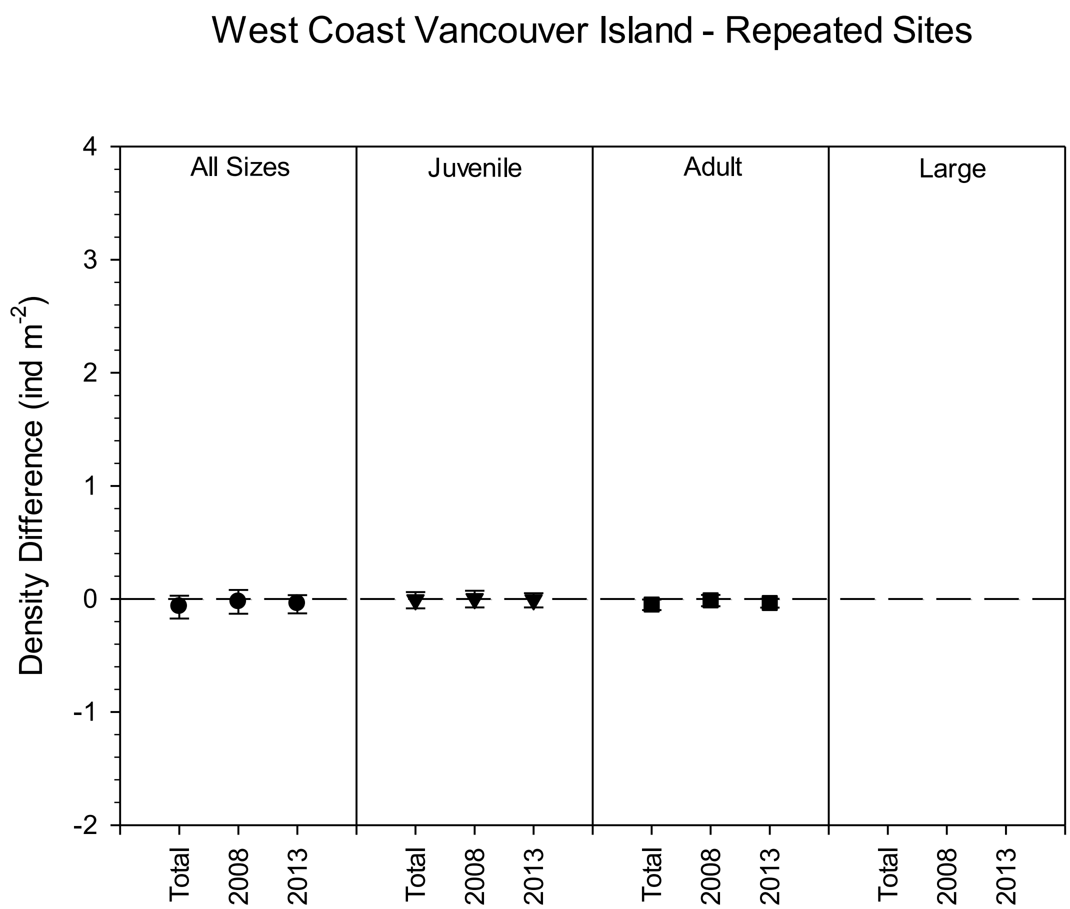


Figure 36. Estimated density difference of Northern Abalone at repeated index sites in West Coast Vancouver Island Region. Estimated density difference is shown for the size classes: ‘All’ (≥ 20 mm), ‘Juvenile’ (≥ 20 mm and < 70 mm SL), ‘Adult’ (≥ 70 mm SL) and ‘Large’ (≥ 100 mm SL). Values are mean estimated density difference ± 95% credible interval between a given survey year and the survey year prior. ‘Total’ is the estimated density difference between 2013 and 2003. Credible intervals that overlap the dashed line indicate no change in density.

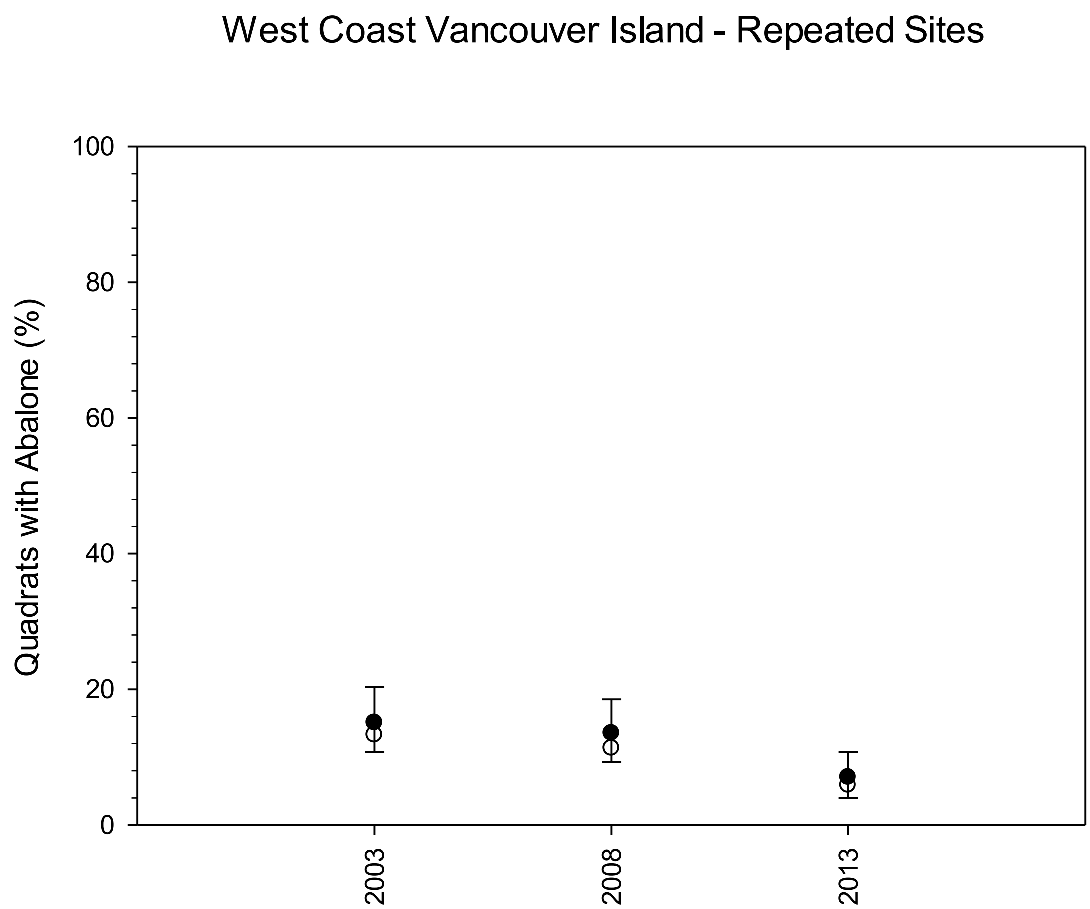


Figure 37. The estimated percentage of quadrats with Northern Abalone for repeated sites in the West Coast Vancouver Island Region. Values are the mean estimated percentage of quadrats ± 95% credible interval (filled symbols) and the observed percentage of quadrats (open symbols) with at least one Northern Abalone.

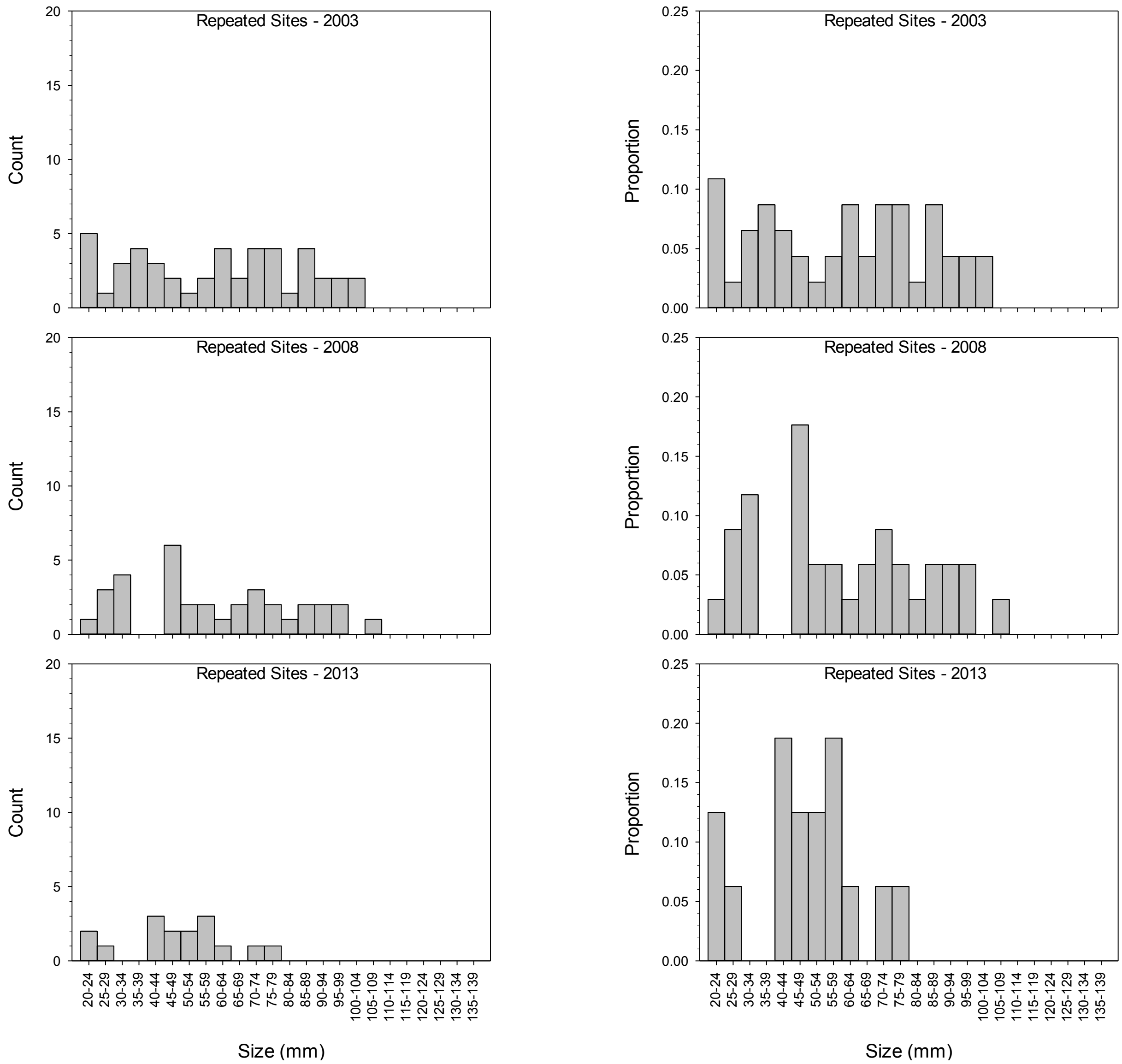


Figure 38. Size frequency histograms of Northern Abalone between 20 and 139 mm shell length, measured at repeated index sites during surveys in the West Coast Vancouver Island Region from 2003 to 2013. The absolute number of Abalone measured and the relative proportion are shown for each 5-mm size bin. Data are hedged at 20 mm due to the cryptic nature and difficulty in detecting Abalone smaller than this size. No Abalone greater than 139 mm were observed.

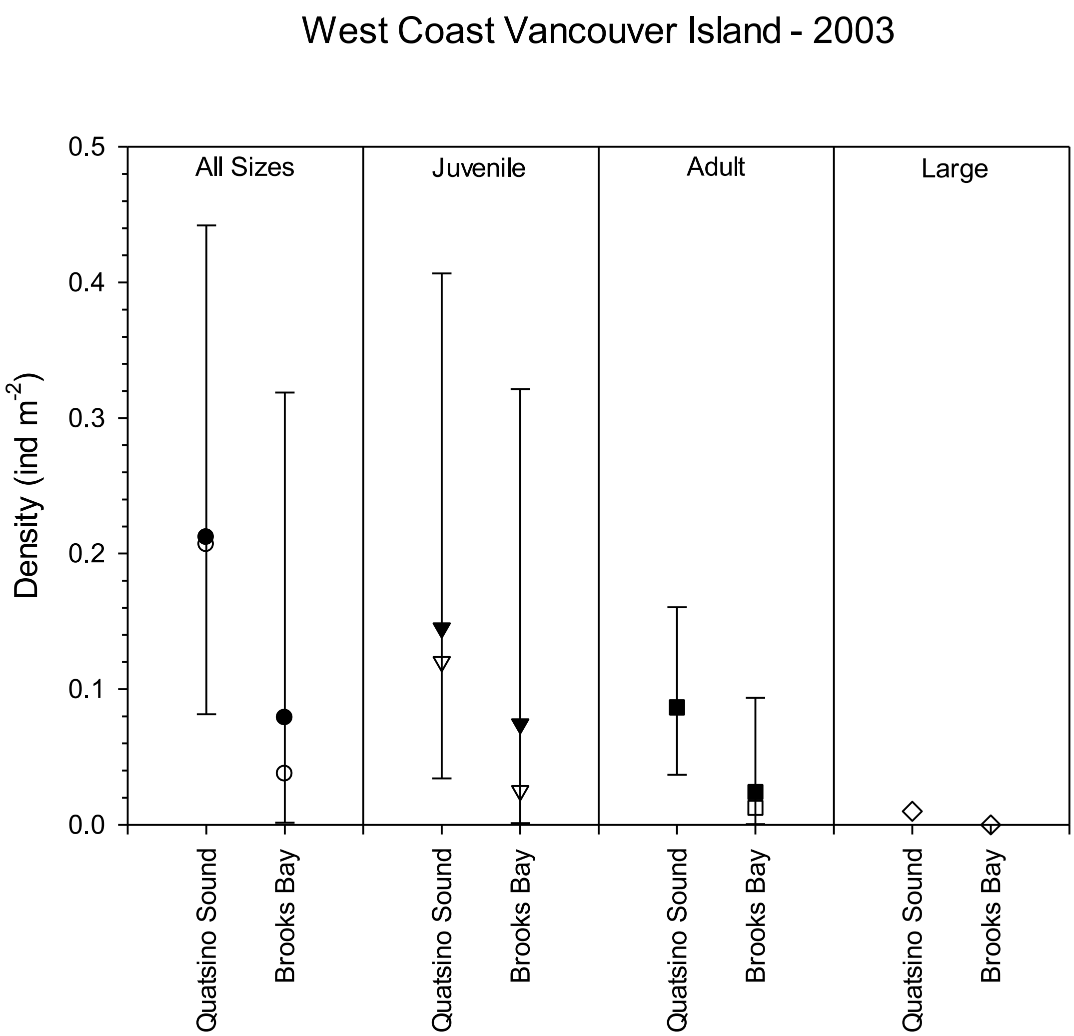


Figure 39. Estimated density of Northern Abalone at all index sites surveyed in the West Coast Vancouver Island Region in 2003, 2008, and 2013. Estimated densities are given for the size class: ‘All’ (≥ 20 mm), ‘Juvenile’ (≥ 20 mm and < 70 mm SL), ‘Adult’ (≥ 70 mm SL) and ‘Large’ (≥ 100 mm SL). Values are mean estimated density ± 95% credible interval (filled symbols). Open symbols are the observed values for reference.

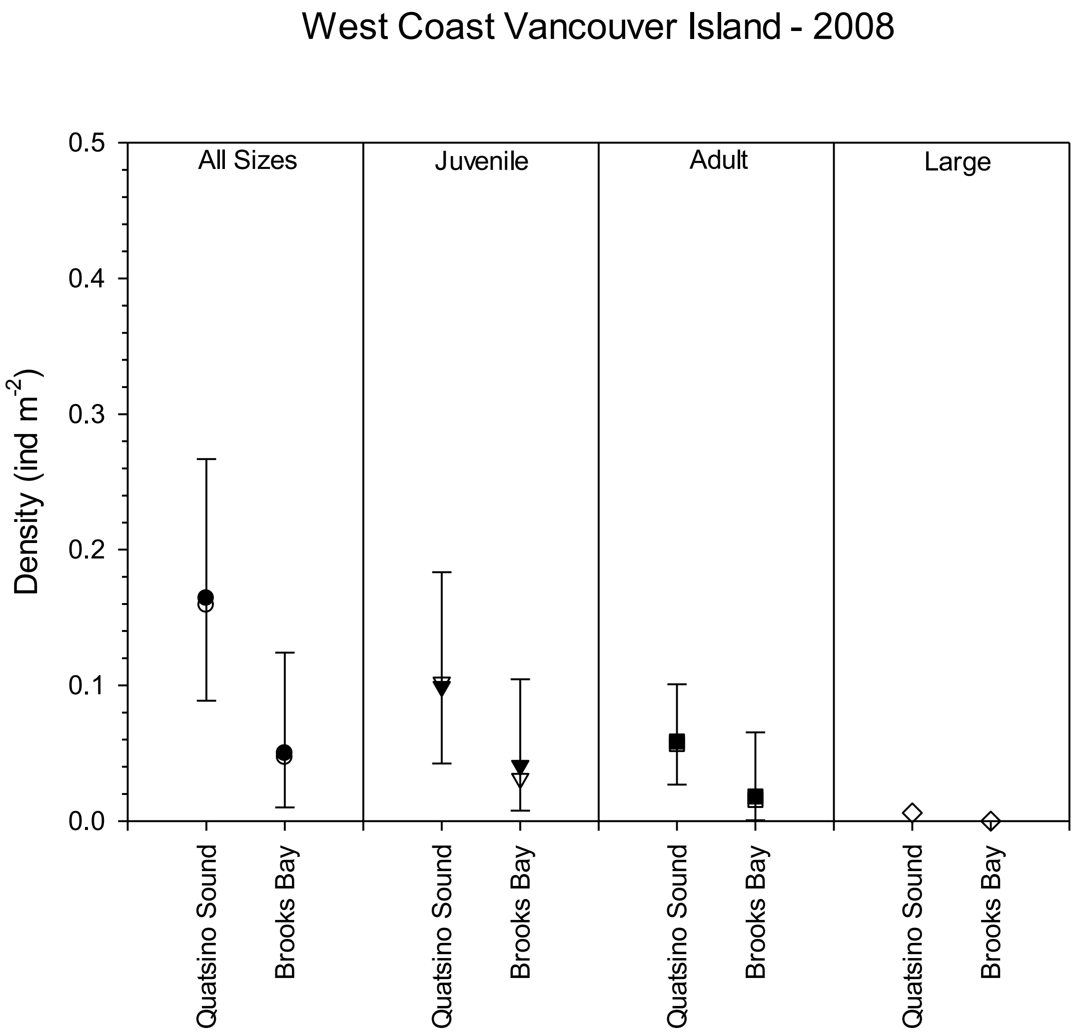


Figure 39. Con't.

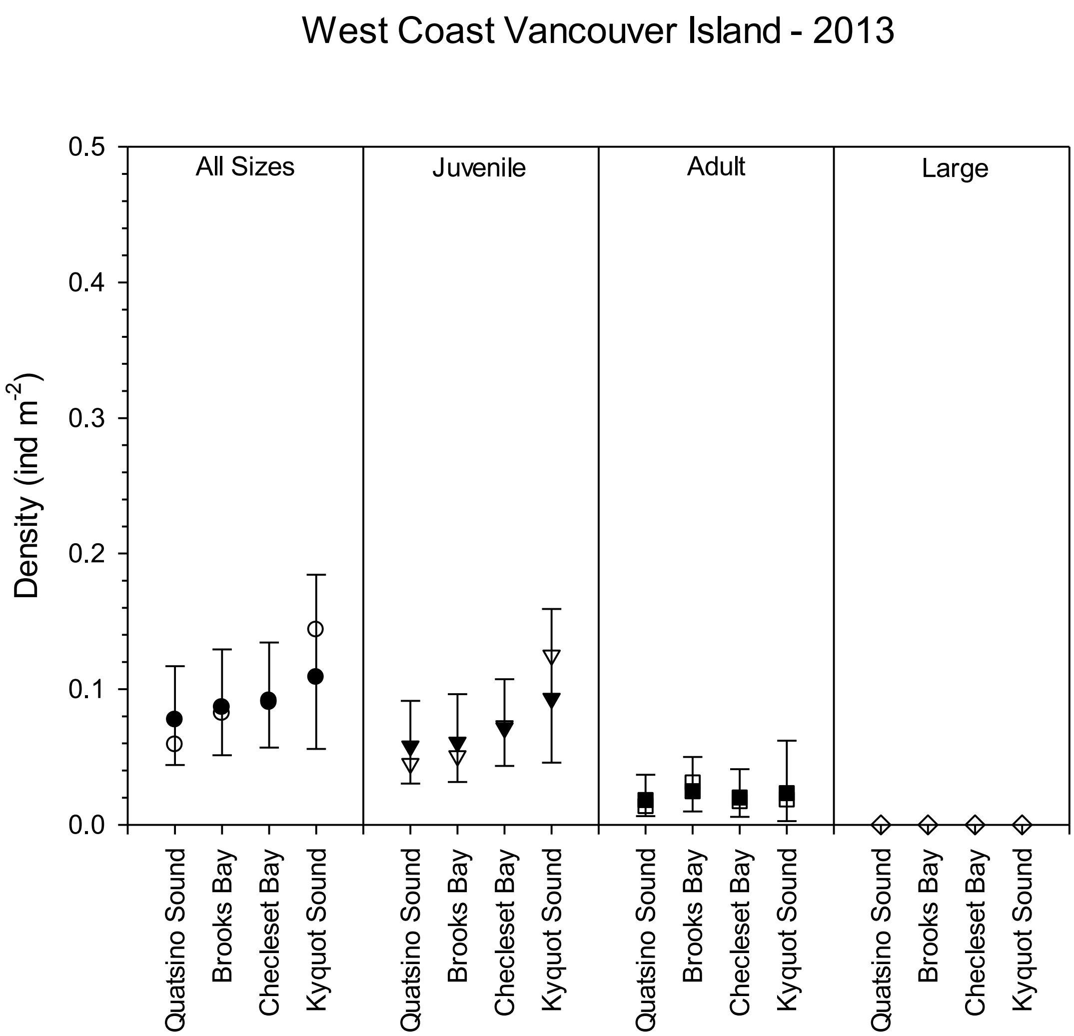


Figure 39. Con't.

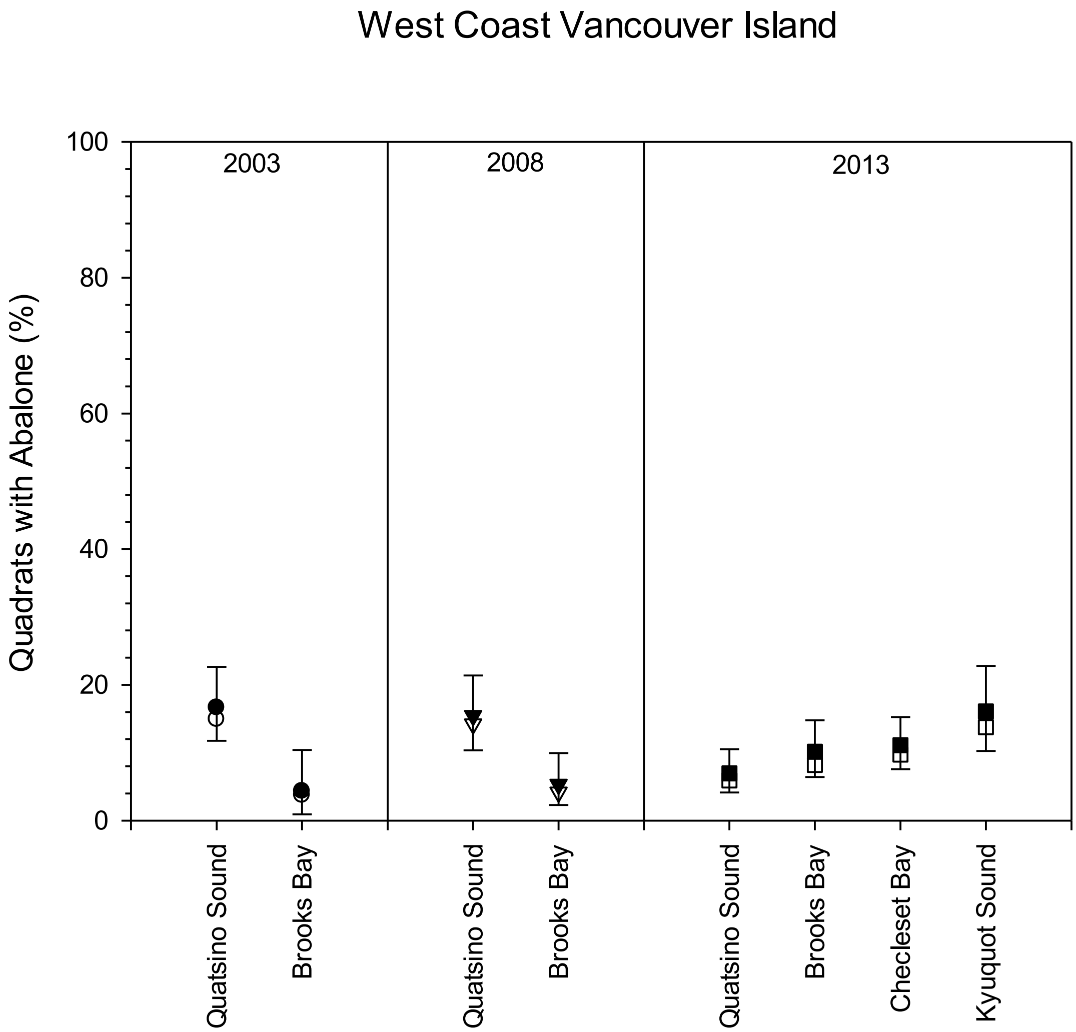


Figure 40. The estimated percentage of quadrats with Northern Abalone for all Sites surveyed in the Quatsino Sound, Brooks Bay, Checleset Bay, and Kyuquot Sound Areas of the West Coast Vancouver Island Region, 2003 to 2013. Values are the mean estimated percentage of quadrats ± 95% credible interval (filled symbols) and the observed percentage of quadrats (open symbols) with at least one Northern Abalone.

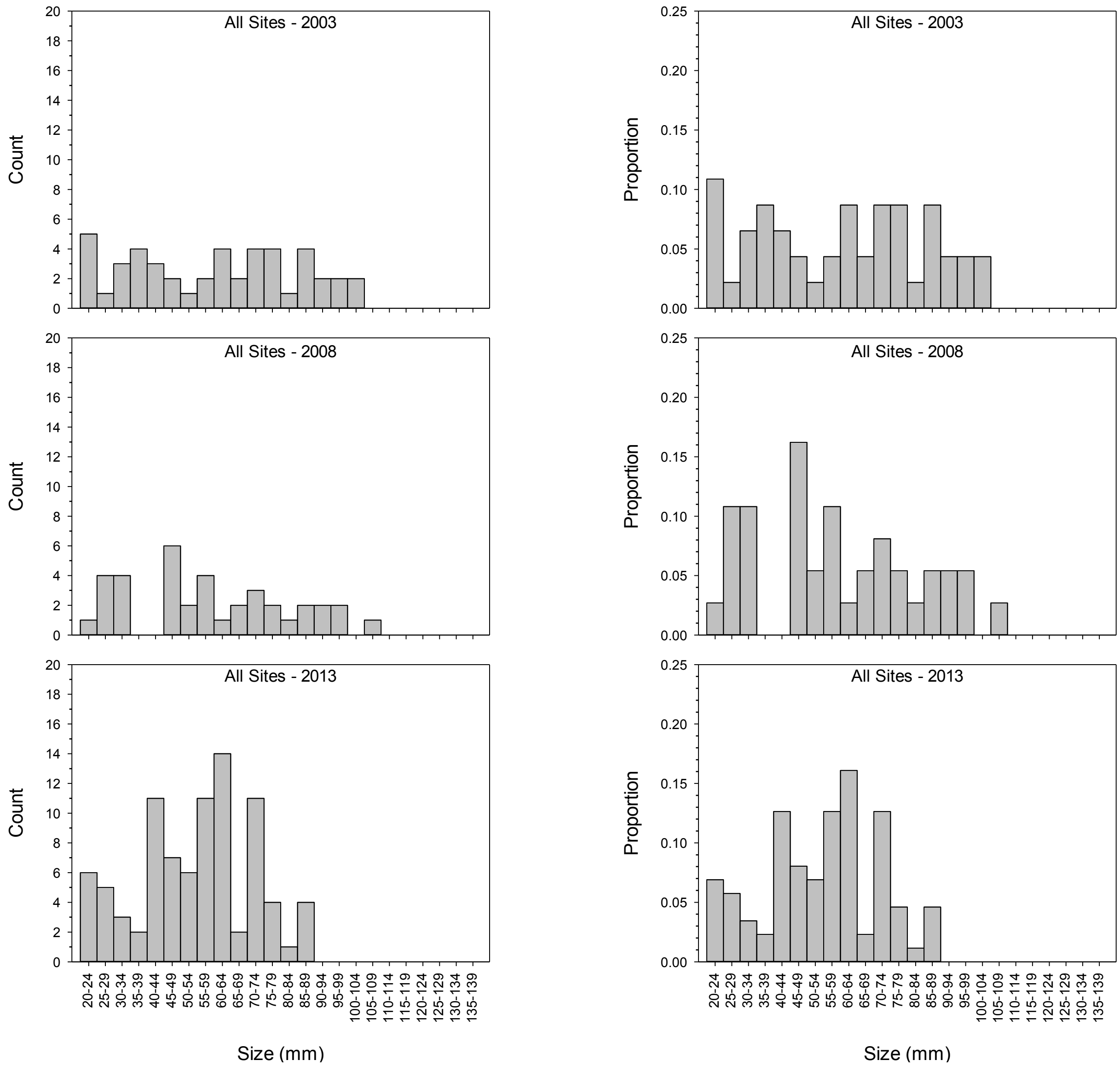


Figure 41. Size frequency histograms of Northern Abalone between 20 and 139 mm shell length, measured at all index sites surveyed in the West Coast Vancouver Island Region from 2003 to 2013. The absolute number of Abalone measured and the relative proportion are shown for each 5-mm size bin. Data are hedged at 20 mm due to the cryptic nature and difficulty in detecting Abalone smaller than this size. No Abalone greater than 139 mm were observed.

Appendix 1. Dive Summary from the 2008 West Coast Haida Gwaii Abalone index site survey.

	Date		Dive Time			Depth (m)			Abalone			Urchins	
Site	Month	Day	Start	Finish	Minutes	Max	Min	# of Quadrats	Measured	Not Measured	Density (m^{-2})	Count	Density (m^{-2})
Hippa Island													
H07	5	16	13:16	13:54	38	3	0	16	40	1	2.56	131	8.19
H09	5	16	10:26	11:00	34	4	1	16	13	0	0.81	168	10.50
H13	5	16	13:59	14:27	28	0	-1	8	0	0	0.00	5	0.63
H18	5	17	9:59	10:45	46	4	0	16	22	1	1.44	81	5.06
H19	5	16	14:41	15:32	51	3	1	16	10	3	0.81	19	1.19
H31	5	17	15:10	15:24	14	2	0	8	0	0	0.00	0	0.00
H32	5	16	15:09	15:59	50	2	-1	16	6	0	0.38	210	13.13
H41	5	17	8:54	9:12	18	6	0	16	12	0	0.75	144	9.00
H44	5	16	9:14	10:11	57	4	3	16	4	0	0.25	40	2.50
H46	5	16	12:51	13:05	14	0	0	8	0	0	0.00	22	2.75
H48	5	17	13:54	14:35	41	3	0	16	11	0	0.69	20	1.25
Englefield Bay													
E04	5	15	10:50	11:12	22	5	-1	16	4	0	0.25	157	9.81
E05	5	14	14:49	15:09	20	5	0	16	0	0	0.00	34	2.13
E06	5	14	9:13	9:54	41	2	0	16	7	0	0.44	288	18.00
E08	5	15	13:28	14:08	40	5	0	16	38	0	2.38	120	7.50
E10	5	13	10:28	11:21	53	4	-1	16	38	0	2.38	181	11.31
E11	5	14	10:45	10:53	8	7	0	8	0	0	0.00	18	2.25
E15	5	13	13:46	13:49	3	6	1	4	23	0	5.75	171	42.75
E18	5	15	9:51	10:27	36	2	-2	16	27	0	1.69	130	8.13
E22	5	12	14:52	15:52	60	6	5	16	5	0	0.31	4	0.25
E23	5	12	13:59	14:25	26	4	0	16	19	0	1.19	255	15.94
E29	5	15	8:32	9:01	29	3	-1	16	1	4	0.31	39	2.44
E34	5	12	13:59	14:20	21	3	1	16	53	0	3.31	255	15.94
E39	5	13	9:20	9:39	19	5	0	8	1	0	0.13	324	40.50
E40	5	14	15:42	16:13	31	4	0	16	9	0	0.56	316	19.75
E41	5	13	10:04	10:51	47	4	-1	16	9	0	0.56	190	11.88
E43	5	15	14:51	15:30	39	4	1	16	27	1	1.75	196	12.25
E49	5	14	13:19	13:29	10	4	1	8	0	0	0.00	0	0.00
Gowgaia Bay													
G01	5	8	15:06	15:33	27	4	0	16	15	15	1.88	260	16.25
G03	5	8	13:41	14:51	70	5	1	16	21	0	1.31	145	9.06
G05	5	9	13:59	14:43	44	4	1	14	34	0	2.43	228	16.29
G08	5	9	14:08	14:15	7	1	1	8	0	0	0.00	27	3.38
G12	5	9	14:31	14:55	24	3	-1	16	0	0	0.00	91	5.69
G15	5	9	13:09	13:43	34	4	1	16	0	38	2.38	145	9.06
G23	5	9	13:03	13:35	32	4	1	16	6	1	0.44	453	28.31
G25	5	8	15:05	15:52	47	3	-2	16	18	0	1.13	112	7.00
G27	5	8	13:47	14:23	36	11	5	16	18	0	1.13	355	22.19
G29	5	8	16:08	16:22	14	0	-1	8	0	0	0.00	0	0.00

Appendix 2. Dive Summary from the 2013 West Coast Haida Gwaii Northern Abalone index site survey.

	Date		Dive Time			Depth (m)			Abalone			Urchins	
Site	Month	Day	Start	Finish	Minutes	Max	Min	# of Quadrats	Measured	Not Measured	Density (m^{-2})	Count	Density (m^{-2})
Hippa Island													
H07	5	3	11:03	12:20	77	2	0	16	20	0	1.25	367	22.94
H09	5	3	9:20	10:29	69	2	1	16	47	0	2.94	163	10.19
H13	5	3	14:19	14:54	35	2	1	16	15	0	0.94	1	0.06
H18	5	2	14:08	14:59	51	7	2	16	13	0	0.81	85	5.31
H19	5	3	11:59	13:03	64	2	1	16	26	0	1.63	102	6.38
H24	5	3	13:02	13:49	47	5	1	16	4	0	0.25	95	5.94
H32	5	3	10:37	11:34	57	2	-1	16	7	0	0.44	140	8.75
H35	5	3	9:12	10:14	62	3	-1	16	36	0	2.25	248	15.50
H41	5	2	13:53	14:44	51	8	1	16	15	1	1.00	198	12.38
H44	5	2	15:32	16:26	54	3	1	16	16	0	1.00	41	2.56
H46	5	3	14:54	15:14	20	2	-1	8	0	0	0.00	24	3.00
H48	5	2	15:22	16:01	39	4	1	16	3	0	0.19	28	1.75
H51	5	2	16:56	18:07	71	5	2	16	32	0	2.00	84	5.25
Englefield Bay													
E04	5	6	9:47	11:06	79	6	1	16	64	1	4.06	132	8.25
E06	5	5	13:16	14:49	93	3	0	16	50	1	3.19	288	18.00
E08	5	5	16:39	17:50	71	9	4	16	52	0	3.25	91	5.69
E10	5	5	9:25	10:19	54	4	0	16	18	0	1.13	196	12.25
E11	5	5	15:26	16:13	47	7	2	16	11	0	0.69	22	1.38
E15	5	5	10:52	11:51	59	4	1	16	30	0	1.88	159	9.94
E18	5	5	10:27	11:42	75	2	-1	16	51	0	3.19	68	4.25
E22	5	5	11:36	12:37	61	4	2	16	27	0	1.69	88	5.50
E23	5	5	14:06	14:59	53	3	0	16	9	0	0.56	119	7.44
E29	5	6	8:15	9:26	71	4	0	16	35	0	2.19	40	2.50
E34	5	5	12:29	13:44	75	5	1	16	50	0	3.13	214	13.38
E39	5	5	9:57	11:09	72	7	1	16	50	0	3.13	439	27.44
E40	5	6	8:19	9:49	90	4	-1	16	49	1	3.13	344	21.50
E41	5	5	9:06	9:29	23	10	3	8	0	0	0.00	5	0.63
E43	5	6	12:18	13:43	85	3	0	16	42	1	2.69	297	18.56
E45	5	6	11:41	13:00	79	5	1	16	124	0	7.75	481	30.06
E51	5	5	16:02	16:57	55	4	-1	16	20	0	1.25	31	1.94

Appendix 2. Con't.

Site	Date		Dive Time			Depth (m)		# of Quadrats	Abalone			Urchins	
	Month	Day	Start	Finish	Minutes	Max	Min		Measured	Not Measured	Density (m^{-2})	Count	Density (m^{-2})
Gowgaia Bay													
G01	5	7	8:42	10:01	79	4	1	16	16	0	1.00	155	9.69
G02	5	7	15:16	16:11	55	4	0	16	7	0	0.44	86	5.38
G03	5	7	10:32	11:43	71	5	3	16	28	1	1.81	111	6.94
G05	5	6	9:26	10:44	78	5	2	16	39	0	2.44	129	8.06
G06	5	8	10:23	11:19	56	7	4	16	7	0	0.44	188	11.75
G07	5	8	10:36	11:26	50	5	2	16	33	0	2.06	80	5.00
G08	5	7	13:35	14:11	36	2	0	16	2	0	0.13	93	5.81
G12	5	7	14:29	15:07	38	4	-1	16	3	0	0.19	39	2.44
G13	5	8	11:48	12:40	52	2	-1	16	22	0	1.38	161	10.06
G15	5	7	8:29	9:18	49	9	2	16	13	0	0.81	210	13.13
G17	5	8	9:11	9:32	21	3	2	8	0	0	0.00	25	3.13
G19	5	8	8:53	9:59	66	5	3	16	9	0	0.56	274	17.13
G23	5	7	11:11	12:00	49	3	2	16	20	0	1.25	147	9.19
G25	5	7	13:43	14:39	56	4	0	16	33	0	2.06	75	4.69
G26	5	8	8:16	8:53	37	6	1	16	3	0	0.19	2	0.13
G32	5	8	14:13	15:05	52	6	2	16	17	0	1.06	74	4.63
G33	5	8	11:52	12:53	61	5	0	16	42	1	2.69	92	5.75

Appendix 3. Habitat data from the 2008 West Coast Haida Gwaii index site survey. See DFO (2016) for a description of the methodology and a complete list of substrate and algae codes.

	Substrate			Slope	Canopy			Understory			Turf			Encrusting
Site	1	2	3	%	%	Sp 1	Sp 2	%	Sp 1	Sp 2	%	Sp 1	Sp 2	%
Hippa Island														
H07	1	2	3	21	5	NT		10	LT	DL	5	RB	BF	90
H09	1	2	5	19	0			30	LT	DL	40	AC	DV	90
H13	3	5	7	15	25	NT		100	CY	AL	20	RF	RB	20
H18	1	2	3	27	0			30	AM	LT	30	RF	BF	90
H19	3	4		11	70	NT		80	CY	CO	40	DY	UL	90
H31	4	3	10	30	0			70	AF		30	AC	DY	50
H32	2	5	4	23	5	NT	EG	30	DL	LT	25	AC	RF	60
H41	1	2	5	40	5	NT		10	LT	AM	10	BF	RF	90
H44	2	3	7	10	2	NT		2	AL	LA	70	DY	AC	90
H46	10	3	4	4	20	MA		35	LS	AG	20	CP	AC	5
H48	4	5	3	17	10	NT		40	DV	CY	30	UL	AC	60
Englefield Bay														
E04	1	2		38	5	NT	EG	5	DV	PH	5	RH	RF	70
E05	1			30	0			0			2	AC		80
E06	2	3	4	15	2	NT		30	PH	DL	5	AC	RF	70
E08	1	2	3	34	5	NT		5	AM		5	UL	PO	90
E10	2	1	3	30	15	NT		30	PH	AL	10	AC	RH	95
E11	2	10		88	0			0			0			90
E15	2	1	4	15	25	NT		50	LT	DL	2	RH	AC	90
E18	1	2	10	21	5	NT		10	AM	DV	30	UL	AC	80
E22	3	4	5	8	0			60	NT	LA	20	RF	GF	50
E23	2	3	4	27	0			2	AL	UL	0			60
E29	3	4	10	23	0			5	DV	NT	10	BH	RH	60
E34	1	2	3	11	0			5	AM	DL	10	AC	RB	100
E39	1	3		61	2	PT		0			0			100
E40	2	11		27	0			2	DL	EG	0			90
E41	1	2	5	30	0			15	AL	LS	5	AC		95
E43	1	2	3	17	5	NT		5	AM	CO	0			90
E49	2	10	4	42	0			70	AF		15	AC		20
Gowgia Bay														
G01	1	3		23	5	NT		10	CO	DE	2	AC		100
G03	1	2	3	30	30	NT		50	NT	LT	20	RB	AC	80
G05	1	2	3	20	20	NT		20	NT	PT	20	AC	BF	90
G08	1	2	3	8	2	NT		0			2	AC		80
G12	1	2	3	19	2	MA		30	PH	EG	10		AC	80
G23	1	2	3	19	2	NT		30	PT	ZO	10	AC	RH	90
G25	1	2	3	25	2	EG	NT	30	AL	DL	5	AC	RH	90
G27	1			34	0			0			2	AC	RF	100
G29	3	7		15	0			80	ZO		75	AC	RB	0

Appendix 4. Habitat data from the 2013 West Coast Haida Gwaii Abalone index site survey. See DFO (2016) for a description of the methodology and a complete list of substrate and algae codes.

	Substrate			Slope	Canopy			Understory			Turf			Encrusting
Site	**1**	**2**	**3**	**%**	**%**	**Sp 1**	**Sp 2**	**%**	**Sp 1**	**Sp 2**	**%**	**Sp 1**	**Sp 2**	**%**
Hippa Island														
H07	3			19	0			5	NT	DE	5	BH	RF	90
H09	2	1	4	10	0			10	DL		5	AC		80
H13	7	4		6	5	NT		5	AL	DY	5	BF	RF	30
H18	1	2	3	32	0			0			5	RF		70
H19	2	3	5	13	5	NT		50	CY	GF	20	GF		50
H24	3	4	6	19	20	NT		20	CO	NT	20	AC		70
H32	1	5	4	19	0			10	CY	LT	10	UL		70
H35	2	3	10	23	0			0			0			90
H41	1	2	5	42	0			0			0			80
H44	1	2		19	0			10	DL	LT	30	AC	DL	80
H46	1	7	10	30	0			0			15	AC		25
H48	3	4	10	19	0			0			5	BF	AC	30
H51	1	2		21	0			50	NT	LB	50	AC	DL	90
Englefield Bay														
E04	2	10		34	0			0			0			80
E06	2			25	0			0			0			100
E08	2			30	0			0			0			80
E10	2			23	0			0			5	BH	BB	70
E11	1	10		34	0			0			0			60
E15	3	1	2	15	10	NT		10	CO	DM	5	DY	AC	60
E18	1	2	10	19	0			5	AL	PH	5	BB	AC	50
E22	2	3	4	15	10	NT		10	NT	CY	5	NT	CY	90
E23	1	3		23	0			0			5	BB	AC	60
E29	3	4	8	23	0			0			0			70
E34	2	10		17	0			0			0			70
E39	1	2		38	0			0			0			90
E40	1	2	10	32	0			10	PH	CO	10	AC	RF	80
E41	2			84	0			30	NT	DL	60	DL	RF	10
E43	2	3	1	19	0			5	AL	NT	5	BB	AL	50
E45	1	2	3	25	0			0			0			100
E51	1	2	3	30	0			0			10	NT	RH	60

Appendix 4. Con't.

Site	Substrate			Slope	Canopy			Understory			Turf			Encrusting
	1	2	3	%	%	Sp 1	Sp 2	%	Sp 1	Sp 2	%	Sp 1	Sp 2	%
Gowgia Bay														
G01	1	2	3	19	5	NT		10	NT	CO	50	AC	RF	70
G02	2	1	3	23	0			5	PH		5	AC	DL	80
G03	1	3	2	17	5	NT		10	LB	LS	10	DN	AC	90
G05	2	3		15	0			40	NT	LB	40	LB	CO	80
G06	1	2		17	10	NT		20	DM	CO	10	DY	AC	80
G07	2	3	4	23	0			20	DL	CO	10	AC	DL	80
G08	2	3	10	13	0			0			0			60
G12	2	3	10	29	0			5	BF		5	BF		60
G13	2	3		19	5	NT		50	LB	AL	50	AC	RF	80
G15	2	10	1	42	0			0			0			40
G17	4	3	10	11	0			0			5	AC		50
G19	3	1		8	10	NT		25	LB	LS	10	AC	RF	80
G23				11	0			10	PT	LB	5	AC		90
G25	3	1	10	23	0			0			5	AC	BF	60
G26	4	5	7	30	80	MA		10	NT	PT	40	AC	PH	40
G32				23	0			50	LB	LS	30	AC		80
G33	1	2	10	30	5	NT		30	DM	LB	50	AC	RF	80

Appendix 5. Dive Summary from the 2012 East Coast Haida Gwaii Northern Abalone index site survey.

	Date		Dive Time			Depth (m)			Abalone			Urchins	
Site	Month	Day	Start	Finish	Minutes	Min	Max	# of Quadrats	Measured	Not Measured	Density (m^{-2})	Count	Density (m^{-2})
Cumshewa Inlet													
76	4	29	8:48	9:29	41	-1	0	16	0	0	0.00	40	2.50
77	4	28	9:25	10:08	43	-1	3	16	0	0	0.00	0	0.00
78	4	28	15:25	15:57	32	2	3	16	0	0	0.00	47	2.94
78-10	4	28	14:28	14:59	31	6	7	16	0	0	0.00	0	0.00
78-16	4	28	10:36	11:16	40	4	4	16	0	0	0.00	0	0.00
78-18	4	29	10:06	10:52	46	0	2	16	6	0	0.38	50	3.13
79-54	4	28	14:24	15:10	46	2	2	16	0	0	0.00	0	0.00
79-57	4	29	8:59	10:04	65	2	3	16	3	0	0.19	119	7.44
Selwyn Inlet													
65	4	29	13:48	14:20	32	2	3	16	1	0	0.06	69	4.31
66	4	29	12:43	13:17	34	0	2	16	19	0	1.19	140	8.75
67	4	29	10:46	11:27	41	4	7	16	4	0	0.25	40	2.50
68	4	30	8:41	9:16	35	0	2	16	18	0	1.13	250	15.63
69	4	29	15:02	15:46	44	3	7	16	16	0	1.00	221	13.81
70	4	29	13:47	14:27	40	1	5	16	18	0	1.13	41	2.56
78-23	4	29	14:52	15:40	48	4	6	16	4	0	0.25	239	14.94
79-58	4	29	12:28	13:24	56	3	7	16	30	0	1.88	74	4.63
Tanu Island													
59	4	30	8:55	10:01	66	-1	1	16	3	0	0.19	7	0.44
60	4	30	10:25	11:04	39	0	3	16	15	0	0.94	108	6.75
61	4	30	12:40	13:20	40	-1	2	16	7	1	0.50	137	8.56
62	4	30	15:39	16:11	32	0	2	16	16	0	1.00	67	4.19
63	4	30	16:36	17:06	30	1	2	16	9	0	0.56	372	23.25
64	4	30	11:50	12:27	37	-1	2	16	5	0	0.31	58	3.63
73	4	30	11:21	11:55	34	-1	3	16	8	0	0.50	44	2.75
74	4	30	10:03	10:33	30	1	2	16	8	0	0.50	71	4.44

Appendix 5. Con't.

Site	Date: Month	Date: Day	Dive Time: Start	Dive Time: Finish	Dive Time: Minutes	Depth (m): Min	Depth (m): Max	# of Quadrats	Abalone: Measured	Abalone: Not Measured	Abalone: Density (m^{-2})	Urchins: Count	Urchins: Density (m^{-2})
Upper Juan Perez													
44	5	2	14:15	15:23	68	-1	3	16	21	1	1.38	36	2.25
45	5	2	14:27	15:18	51	-1	2	16	24	0	1.50	49	3.06
46	5	1	11:15	12:02	47	0	4	16	20	0	1.25	276	17.25
48	5	2	8:28	9:18	50	-1	1	16	15	0	0.94	252	15.75
49	5	1	15:27	16:11	44	1	2	16	17	0	1.06	40	2.50
50	5	2	10:06	10:35	29	0	1	16	8	0	0.50	21	1.31
51	5	2	11:04	11:34	30	1	3	16	7	0	0.44	17	1.06
52	5	1	14:20	15:02	42	1	5	16	9	0	0.56	257	16.06
53	5	1	14:49	15:39	50	2	4	16	28	0	1.75	138	8.63
54	5	2	13:08	13:44	36	4	6	16	15	0	0.94	27	1.69
55	5	1	8:44	9:25	41	1	2	16	19	0	1.19	298	18.63
56	5	1	9:45	10:35	50	2	5	16	26	0	1.63	143	8.94
57	5	1	11:02	12:19	77	-2	0	16	0	0	0.00	268	16.75
58	5	1	8:31	9:59	88	-1	3	16	42	0	2.63	217	13.56
Lower Juan Perez													
36	5	4	14:00	15:15	75	1	5	16	21	0	1.31	241	15.06
37	5	4	13:46	14:47	61	-1	3	16	45	0	2.81	189	11.81
38	5	4	10:51	12:00	69	1	7	16	12	0	0.75	58	3.63
39	5	4	10:47	11:36	49	0	4	16	18	0	1.13	107	6.69
40	5	4	9:45	10:22	37	0	2	16	11	0	0.69	40	2.50
41	5	4	8:58	9:23	25	0	4	16	1	0	0.06	17	1.06
42	5	5	8:48	9:39	51	2	5	16	47	0	2.94	95	5.94
43	5	5	10:07	11:14	67	3	5	16	54	0	3.38	86	5.38
78-60	5	5	10:52	11:57	65	0	5	16	30	0	1.88	107	6.69
78-61	5	5	8:46	10:06	80	1	7	16	60	0	3.75	135	8.44
Skincuttle Inlet													
22	5	6	11:06	11:56	50	2	6	16	64	0	4.00	82	5.13
23	5	6	13:55	14:55	60	0	1	16	0	0	0.00	3	0.19
24	5	6	9:40	10:10	30	1	4	16	11	0	0.69	1	0.06
25	5	6	9:27	10:18	51	1	2	16	9	0	0.56	0	0.00
26	5	7	9:43	10:37	54	0	3	16	15	0	0.94	59	3.69
27	5	7	9:25	9:50	25	7	11	16	0	0	0.00	1	0.06
28	5	10	13:29	14:41	72	2	5	16	76	0	4.75	145	9.06
29	5	6	14:04	14:44	40	1	6	16	34	0	2.13	80	5.00
30	5	6	15:14	15:56	42	1	5	16	39	0	2.44	170	10.63
31	5	5	15:42	16:22	40	3	6	16	49	0	3.06	7	0.44
32	5	5	14:31	15:18	47	1	5	16	5	0	0.31	30	1.88
33	5	8	15:08	15:50	42	1	4	16	31	0	1.94	83	5.19
34	5	8	9:12	10:19	67	1	3	16	16	0	1.00	154	9.63
35	5	5	15:14	16:06	52	0	2	16	1	0	0.06	156	9.75

Appendix 5. Con't.

	Date		Dive Time			Depth (m)			Abalone			Urchins	
Site	Month	Day	Start	Finish	Minutes	Min	Max	# of Quadrats	Measured	Not Measured	Density (m^{-2})	Count	Density (m^{-2})
Carpenter Bay													
10	5	14	14:02	15:06	64	1	3	16	0	0	0.00	9	0.56
11	5	14	15:32	16:19	47	1	3	16	16	0	1.00	49	3.06
12	5	14	15:30	16:26	56	0	2	16	3	0	0.19	81	5.06
13	5	14	8:57	9:34	37	3	5	16	3	0	0.19	38	2.38
14	5	14	10:04	10:47	43	-1	3	16	12	0	0.75	226	14.13
15	5	14	11:13	11:52	39	1	4	16	11	0	0.69	86	5.38
17	5	14	14:05	14:48	43	1	5	16	11	0	0.69	87	5.44
18	5	14	10:37	12:00	83	1	2	16	30	0	1.88	162	10.13
19	5	14	8:49	9:53	64	-1	2	16	19	0	1.19	143	8.94
20	5	11	10:56	11:40	44	1	6	16	35	0	2.19	11	0.69
21	5	11	9:03	9:52	49	2	4	16	18	0	1.13	122	7.63
Kunghit Island													
1	5	15	14:57	15:47	50	-1	1	16	9	0	0.56	88	5.50
2	5	16	9:30	10:21	51	-1	1	16	9	0	0.56	95	5.94
3	5	15	14:35	15:32	57	1	3	16	7	4	0.69	65	4.06
4	5	15	8:40	9:28	48	-1	4	16	70	0	4.38	130	8.13
7	5	15	11:45	12:50	65	0	2	16	27	2	1.81	35	2.19
71	5	16	8:16	9:27	71	1	2	16	1	0	0.06	25	1.56
79	5	15	9:10	10:21	71	-1	2	16	9	0	0.56	30	1.88
OR01	5	16	8:13	9:08	55	-1	3	16	16	0	1.00	45	2.81
OR02	5	15	9:51	10:54	63	1	3	16	43	0	2.69	31	1.94
PR02	5	15	13:01	14:11	70	0	1	16	29	0	1.81	61	3.81

Appendix 6. Habitat data from the 2012 East Coast Haida Gwaii Abalone index site survey. See DFO (2016) for a description of the methodology and a complete list of substrate and algae codes.

	Substrate			Slope	Canopy			Understory			Turf			Encrusting
Site	1	2	3	%	%	Sp 1	Sp 2	%	Sp 1	Sp 2	%	Sp 1	Sp 2	%
Cumshewa Inlet														
76	3	4	10	6	30	MA		90	DV	DL	40	AC	UL	40
77	5	6		23	5	NT		20	AM	CY	5	RB	RF	5
78	3	4	10	4	70	NT		40	CY	DV	40	BF	RB	50
78-10	3	10	4	4	5	MA		50	RB	NT	50	RB	RF	10
78-16	5	6	3	4	40	MA	NT	50	CY	PT	30	RF	RB	10
78-18	3	5		15	40	NT		60	PT	PL	30	AC	IR	30
79-54	5	7	6	4	5	MA		60	CY	PT	10	RB	RF	5
79-57	3	4	7	4	70	NT		45	CY	DL	10	DY	RF	60
Selwyn Inlet														
65	3	4	5	8	0			30	CY	NT	5	RF		50
66	3	2		11	5	NT		0			0			80
67	3	1	4	23	10	NT		30	NT	CY	20	RB	RF	50
68	2	1		17	20	EG		30	AL	CO	10	RB	AC	80
69	2	1		27	10	NT		30	DV	CO	10	RB	AC	90
70	2	1		25	10	NT		20	CO	AM	20	AC	RB	90
78-23	3	1	2	11	10	NT		35	CO	CY	10	RH	DY	90
79-58	1	2		27	5	NT		15	AL	DL	5	RH		95
Tanu Island														
59	2			17	10	NT		90	PT	LB	30	RF	RH	10
60	3	4		21	5	NT		10	CY		5	AC		60
61	1	2		19	5	EG		10	CO	CY	5	AC	DY	80
62	3	4		11	5	NT		10	CY	AM	5	AC		70
63	3			10	10	NT		10	CY	AM	5	AC		50
64	3	4	10	17	20	NT	MA	40	DV	CY	10	RF	IR	20
73	4	5	3	21	40	MA		70	AG	LS	0			20
74	3	4	7	8	5	MA		5	AF	LS	0			10

Appendix 6. Con't.

Site	Substrate 1	Substrate 2	Substrate 3	Slope %	Canopy %	Canopy Sp 1	Canopy Sp 2	Understory %	Understory Sp 1	Understory Sp 2	Turf %	Turf Sp 1	Turf Sp 2	Encrusting %
Upper Juan Perez														
44	2	1	3	21	10	NT		70	LB	CO	60	AC	RF	80
45	2	3	10	13	0			30	CY	DL	40	GH	UL	50
46	2			29	10	NT		10	CO	AM	5	GH	AC	90
48	2			10	10	NT	MA	10	CY	DV	10	RB	AC	90
49	2	1	11	8	0			0			5	AC		80
50	3	4		10	10	MA		20	CY	AM	40	UL	AC	80
51	2	4		15	0			0			25	BH	RH	60
52	1	2		27	5	NT		5	AL	CO	5	AC	RB	80
53	1	2		10	25	NT		25	DL	CO	10	RH	BH	95
54	2	10		8	0			10	DV		30	AC		40
55	2	4		8	10	NT		20	CO	DV	10	RB	AC	90
56	2	3		21	5	NT		5	CO		5	RB		90
57	3	2	1	13	10	EG		80	LB	CY	60	AC	RF	70
58	1	2		27	10	EG	NT	80	LB	LT	40	AC	RF	70
Lower Juan Perez														
36	1	2		27	5	NT		30	DL	CO	20	RH	AC	95
37	2			25	0			10	DV	DL	10	AC	GH	90
38	2			42	0			0			5	AC	RB	90
39	1	3	2	25	10	NT		40	CO	LA	40	AC	DV	90
40	2			15	0			0			70	AC	GH	80
41	2	10		23	0			30	AF		10	AC		80
42	2			23	10	NT		10	CO		10	AC	BF	90
43	2	1		23	0			0			5	AC		90
78-60	2	1		36	10	NT		20	CO	NT	10	AC		90
78-61	1			42	15	NT		20	DE	LA	20	AC	RH	100
Skincuttle Inlet														
22	2	3		25	0			10	CO		0			90
23	3	4	7	10	30	MA		70	LB	LS	20	DU	RF	50
24	2	1	4	15	0			10	AF		30	AC		20
25	3	1	4	4	20	MA		30	CO	LS	10	AC	DY	80
26	4			15	0			0			0			70
27	7	3	10	27	30	MA		60	AF		10	AC		10
28	2	1		23	0			0			5	RB	DY	80
29	2			27	0			10	DV	DL	0			90
30	2			27	10	NT		10	DL	DV	10	RB	IR	80
31	2	1	4	15	10	MA		10	MA	DL	20	AC		90
32	2			25	10	NT		30	PT	PL	70	AC	IR	30
33	1	2	3	17	20	NT		50	CY	AL	10	AC		80
34	3	1	4	13	40	NT		40	CY	AL	10	AC		70
35	3			11	20	NT		25	CY	CO	5	LA	AC	60

Appendix 6. Con't.

Site	Substrate 1	Substrate 2	Substrate 3	Slope %	Canopy %	Canopy Sp 1	Canopy Sp 2	Understory %	Understory Sp 1	Understory Sp 2	Turf %	Turf Sp 1	Turf Sp 2	Encrusting %
Carpenter Bay														
10	3	4	7	10	60	MA		50	AG	MA	10	AC		30
11	2	1		17	0			0			5	AC		80
12	3	1	4	15	0			10	LA		5	AC		40
13	1	2		13	5	NT		5	DL	DV	5	DY	AC	85
14	2	1		23	0			5	LS	PH	5	AC		80
15	1	2	3	15	10	NT		5	DV		15	AC	BH	90
17	1	4		27	0			5	GR		5	AC		80
18	3	4	1	11	60	NT		50	CY	PT	20	AC		50
19	1	2		15	30	NT		20	DU	PH	30	AC		50
20	1	2		30	0			0			5	AC		70
21	3	4	5	11	0	NT		30	CY	CO	20	RH	DY	70
Kunghit Island														
1	1	2		13	20	MA		20	DE	DV	70	AC	UL	50
2	3	1	4	6	40	MA		20	LB	MA	10	AC	DY	80
3	3	1	4	15	20	NT		20	CY	CO	10	AC	DY	90
4	2	1	3	27	5	NT		5	DE		5	AC		90
7	3	1		15	10	NT	PT	30	LT	PT	40	AC	DY	60
71	2	7		4	0			50	RF	UL	30	BF	AC	30
79	3	1		23	70	NT	PT	80	CO	PL	10	DY	AC	70
OR01	1	2		25	5	MA		20	LB	CY	30	AC		80
OR02	3	2		17	5	NT		10	DE	CY	10	AC		90
PR02	3	4	5	6	30	NT		40	CY	CO	10	AC		70

Appendix 7. Dive summary from the 2011 Central Coast Abalone index site survey.

	Date		Dive Time			Depth (m)			Abalone			Urchins	
Site	Month	Day	Start	Finish	Minutes	Min	Max	# of Quadrats	Measured	Not Measured	Density (m^{-2})	Count	Density (m^{-2})
North Banks Island													
44	5	9	9:11	10:24	73	-2	1	16	4	0	0.25	460	28.75
45	5	9	9:20	10:20	60	-1	2	16	14	1	0.94	596	37.25
46	5	1	11:57	13:05	68	0	2	16	45	1	2.88	173	10.81
47	5	1	10:21	11:05	44	1	3	16	12	0	0.75	142	8.88
48	5	9	10:58	11:52	54	-1	1	16	3	0	0.19	549	34.31
49	5	9	10:59	12:19	80	-1	1	16	4	0	0.25	170	10.63
50	5	1	12:03	12:46	43	0	2	16	0	0	0.00	2	0.13
51	5	1	10:24	11:24	60	-2	1	16	0	0	0.00	0	0
52	5	9	13:11	14:11	60	-1	2	16	16	0	1.00	61	3.81
53	5	9	13:00	13:32	32	0	2	16	17	0	1.06	138	8.63
Oswald Bay													
38	5	8	18:25	19:12	47	0	2	16	9	0	0.56	46	2.88
39	5	8	18:08	19:09	61	-2	3	16	19	1	1.25	111	6.94
40	5	8	19:34	20:12	38	0	1	16	6	0	0.38	108	6.75
41	5	5	13:56	14:36	40	0	1	16	12	0	0.75	254	15.88
42	5	5	13:55	14:52	57	-1	3	16	5	0	0.31	200	12.5
43	5	5	15:20	16:14	54	-2	2	16	33	0	2.06	68	4.25
43A	5	5	15:33	16:03	30	-1	1	8	0	0	0.00	39	4.88
Pemberton Bay													
33	5	6	9:57	10:34	37	2	5	16	10	0	0.63	49	3.06
34	5	6	13:08	13:54	46	-1	5	16	11	0	0.69	309	19.31
35	5	6	11:58	12:51	53	1	4	16	21	0	1.31	694	43.38
36	5	6	10:07	11:10	63	1	3	16	22	0	1.38	94	5.88
Lotbiniere Bay													
21	5	3	10:07	10:59	52	2	3	16	1	0	0.06	15	0.94
22	5	5	10:18	10:52	34	1	3	16	3	0	0.19	17	1.06
23	5	3	13:42	15:05	83	0	2	16	28	0	1.75	65	4.06
24	5	3	13:13	14:04	51	0	1	16	1	0	0.06	148	9.25
25	5	3	15:45	16:45	60	1	3	16	2	0	0.13	54	3.38
27	5	3	11:12	12:17	65	0	0	16	8	0	0.50	1	0.06
28	5	5	10:08	10:47	39	0	2	16	2	0	0.13	44	2.75
29	5	3	16:13	16:37	24	1	6	16	7	0	0.44	116	7.25
30	5	3	14:27	15:41	74	-1	2	16	45	1	2.88	89	5.56

Appendix 7. Con't.

	Date		Dive Time			Depth (m)			Abalone			Urchins	
Site	Month	Day	Start	Finish	Minutes	Min	Max	# of Quadrats	Measured	Not Measured	Density (m^{-2})	Count	Density (m^{-2})
North Aristazabal Island													
13	5	7	8:40	9:24	44	-1	3	16	15	0	0.94	93	5.81
14	5	7	9:47	010:46	59	0	4	16	27	1	1.75	95	5.94
15	5	7	10:21	11:12	51	1	3	16	5	0	0.31	79	4.94
15A	5	7	12:30	13:07	37	0	3	16	26	0	1.63	157	9.81
16	5	7	8:48	9:43	55	0	2	16	4	0	0.25	161	10.06
16A	5	7	12:37	13:30	53	0	2	16	8	0	0.50	113	7.06
17	5	7	14:00	15:00	60	-1	2	16	36	0	2.25	230	14.38
18	5	7	15:14	16:00	46	-1	2	16	16	0	1.00	218	13.63
19	5	7	14:04	14:40	36	-1	0	16	9	0	0.56	127	7.94
20	5	7	15:08	15:41	33	0	2	16	21	0	1.31	160	10
South Aristazabal Island													
2	5	8	11:28	12:18	50	1	3	16	43	1	2.75	183	11.44
3	5	8	8:35	9:17	42	-1	1	16	12	0	0.75	359	22.44
4	4	30	15:06	15:55	49	-1	1	16	8	0	0.50	33	2.06
5	4	30	15:18	15:52	34	-2	2	16	2	0	0.13	105	6.56
6	5	8	8:36	9:33	57	-1	3	16	12	0	0.75	331	20.69
7	5	8	9:58	10:54	56	0	4	16	28	2	1.88	200	12.5
8	5	8	11:14	11:40	26	0	3	16	5	0	0.31	73	4.56
9	5	8	9:55	10:25	30	0	1	16	7	0	0.44	207	12.94
10	4	30	10:27	11:25	58	-1	3	16	5	0	0.31	168	10.5
10A	4	30	10:34	12:03	89	-1	0	16	2	0	0.13	204	12.75
11	4	30	13:28	14:37	69	-1	5	16	14	0	0.88	127	7.94
12	4	30	13:28	14:20	52	-1	3	16	11	0	0.69	68	4.25
Stryker Island													
ST121	5	14	10:10	11:34	84	-2	1	16	0	0	0.00	0	0
ST190	5	14	14:05	15:23	78	0	7	16	36	2	2.38	11	0.69
ST220	5	14	14:15	15:05	50	-1	1	16	6	0	0.38	8	0.5
ST304	5	14	15:52	17:11	79	0	4	16	18	0	1.13	9	0.56
ST359	5	14	15:35	16:27	52	0	5	16	16	0	1.00	227	14.19
ST411	5	14	10:09	11:40	91	0	4	16	11	0	0.69	11	0.69
ST444	5	14	12:00	13:20	80	-1	4	16	24	0	1.50	14	0.88
ST483	5	14	12:04	13:10	66	3	8	16	22	0	1.38	11	0.69

Appendix 7. Con't.

Site	Date: Month	Date: Day	Dive Time: Start	Dive Time: Finish	Dive Time: Minutes	Depth (m): Min	Depth (m): Max	# of Quadrats	Abalone: Measured	Abalone: Not Measured	Abalone: Density (m^{-2})	Urchins: Count	Urchins: Density (m^{-2})
Simonds Group													
SI02	5	15	11:08	12:36	88	-1	3	12	39	2	3.42	17	1.42
SI03	5	15	10:14	11:26	72	0	3	16	38	2	2.50	27	1.69
SI05	5	15	11:50	13:09	79	-1	1	16	10	0	0.63	21	1.31
SI09	5	15	15:31	16:30	59	1	6	16	36	0	2.25	5	0.31
SI16	5	15	13:46	15:02	76	-1	1	16	38	0	2.38	28	1.75
SI20	5	15	8:45	10:18	93	0	2	12	42	8	4.17	18	1.5
SI21	5	15	8:30	9:47	77	1	3	16	39	0	2.44	56	3.5
SI30	5	15	13:55	15:23	88	0	3	16	2	2	0.25	1	0.06
Spider Island													
SP05	5	16	14:55	15:22	27	-1	4	16	5	0	0.31	22	1.38
SP08	5	16	11:12	12:18	66	-1	5	16	3	0	0.19	57	3.56
SP17	5	16	10:30	11:40	70	0	6	16	16	2	1.13	3	0.19
SP32	5	16	9:49	10:44	55	1	3	16	4	0	0.25	9	0.56
SP33	5	16	12:41	14:16	95	-2	2	16	10	0	0.63	8	0.5
SP34	5	16	8:55	10:00	65	0	5	16	13	0	0.81	6	0.38
SP35	5	16	8:34	9:18	44	3	7	16	3	0	0.19	6	0.38
SP36	5	16	12:50	14:22	92	-1	2	16	30	0	1.88	23	1.44

Appendix 8. Dive Summary from the 2016 Central Coast Northern Abalone index site survey.

	Date		Dive Time			Depth (m)			Abalone			Urchins	
Site	Month	Day	Start	Finish	Minutes	Min	Max	# of Quadrats	Measured	Not Measured	Density (m^{-2})	Count	Density (m^{-2})
North Banks Island													
44	5	21	10:23	11:42	79	-1	1	16	41	0	2.56	354	22.13
45	5	21	11:17	12:00	43	0	1	16	21	0	1.31	246	15.38
46	5	20	9:10	10:11	61	0	3	16	79	3	5.13	112	7.00
47	5	21	7:43	9:11	88	2	3	16	46	1	2.94	87	5.44
48	5	21	9:24	10:46	82	-1	1	16	16	0	1.00	512	32.00
49	5	21	8:11	8:57	46	-1	1	16	14	0	0.88	167	10.44
50	5	20	10:58	11:44	46	-3	-1	16	0	0	0.00	0	0.00
51	5	20	8:58	10:08	70	0	3	16	0	0	0.00	3	0.19
52	5	20	11:02	11:35	33	-2	3	16	23	11	2.13	65	4.06
53	5	20	12:06	12:57	51	-1	1	16	42	1	2.69	190	11.88
Oswald Bay													
38	5	12	8:23	9:21	58	-2	1	16	12	0	0.75	22	1.38
39	5	12	9:59	10:41	42	-1	1	16	20	1	1.31	90	5.63
40	5	12	11:04	12:16	72	-1	0	16	21	0	1.31	89	5.56
41	5	12	9:45	10:54	69	0	2	16	47	2	3.06	794	49.63
42	5	12	8:15	8:57	42	-1	1	16	18	0	1.13	297	18.56
43	5	12	11:31	12:17	46	0	2	16	15	1	1.00	91	5.69
Pemberton Bay													
33	5	10	9:57	10:38	41	1	3	16	11	0	0.69	85	5.31
34	5	10	7:58	9:03	65	0	2	16	94	3	6.06	269	16.81
35	5	10	7:49	8:54	65	-1	1	16	62	0	3.88	348	21.75
36	5	10	9:52	11:02	70	0	2	16	102	5	6.69	177	11.06
83-37	5	11	7:47	8:32	45	-2	1	16	15	5	1.25	136	8.50
Lotbiniere Bay													
21	5	11	12:08	12:47	39	0	1	16	9	0	0.56	80	5.00
22	5	11	9:11	10:07	56	0	1	16	4	0	0.25	0	0.00
23	5	10	13:45	14:55	70	0	3	16	50	0	3.13	66	4.13
24	5	10	12:20	13:25	65	0	1	16	15	0	0.94	124	7.75
25	5	10	12:03	12:49	46	1	2	16	47	0	2.94	162	10.13
27	5	11	10:35	11:28	53	-1	1	16	8	1	0.56	46	2.88
28	5	10	14:40	15:03	23	0	2	16	14	0	0.88	74	4.63
29	5	11	10:09	10:53	44	-1	3	16	25	7	2.00	83	5.19
30	5	10	13:18	14:13	55	0	2	16	109	0	6.81	93	5.81
83-31	5	11	8:05	8:42	37	1	3	16	7	0	0.44	154	9.63
83-32	5	11	13:13	14:28	75	0	2	16	6	0	0.38	95	5.94

Appendix 8. Con't.

Site	Date: Month	Date: Day	Dive Time: Start	Dive Time: Finish	Dive Time: Minutes	Depth (m): Min	Depth (m): Max	# of Quadrats	Abalone: Measured	Abalone: Not Measured	Abalone: Density (m^{-2})	Urchins: Count	Urchins: Density (m^{-2})
North Aristazabal Island													
13	5	13	10:36	11:18	42	-1	1	16	0	0	0.00	22	1.38
14	5	13	7:48	8:33	45	-2	2	16	22	2	1.50	76	4.75
15	5	13	7:39	8:32	53	-3	1	16	49	0	3.06	52	3.25
15A	5	16	8:48	9:37	49			16	17	0	1.06	9	0.56
16	5	13	9:03	10:07	64	-1	0	16	40	0	2.50	174	10.88
16A	5	13	10:14	11:14	60	0	2	16	3	0	0.19	74	4.63
17	5	13	12:06	12:42	36	1	3	16	11	0	0.69	170	10.63
18	5	13	13:09	13:57	48	0	4	16	29	0	1.81	263	16.44
19	5	13	14:15	15:07	52	-1	1	16	35	4	2.44	98	6.13
20	5	13	12:32	13:44	72	-1	3	16	65	0	4.06	185	11.56
South Aristazabal Island													
02	5	14	10:19	11:18	59	-2	1	16	15	1	1.00	149	9.31
03	5	14	9:14	9:59	45	-1	2	16	11	0	0.69	186	11.63
04	5	14	15:33	16:55	82	-1	1	16	12	0	0.75	46	2.88
05	5	14	15:25	16:02	37	-1	3	16	11	0	0.69	111	6.94
06	5	14	14:18	15:01	43	-1	4	16	38	0	2.38	176	11.00
07	5	14	12:50	13:45	55	0	4	16	142	0	8.88	130	8.13
08	5	14	11:38	12:18	40	-1	2	16	15	0	0.94	48	3.00
09	5	14	7:57	8:44	47	-2	0	16	9	1	0.63	0	0.00
10	5	14	7:45	8:49	64	-2	0	16	29	3	2.00	7	0.44
10A	5	14	9:14	10:07	53	-2	1	16	10	0	0.63	180	11.25
11	5	14	10:49	12:38	109	-1	2	16	100	4	6.50	199	12.44
12	5	14	13:20	14:40	80	-1	4	16	54	5	3.69	65	4.06
Stryker Island													
ST121	5	8	8:50	9:40	50	3	6	16	9	3	0.75	19	1.19
ST190	5	8	8:49	9:58	69	2	6	16	20	48	4.25	142	8.88
ST220	5	8	10:29	11:44	75	0	2	16	8	3	0.69	62	3.88
ST304	5	8	10:36	11:50	74	1	5	16	154	1	9.69	208	13.00
ST359	5	8	12:44	13:50	66	-2	3	16	46	3	3.06	116	7.25
ST411	5	15	7:45	8:35	50	0	6	16	4	0	0.25	65	4.06
ST444	5	15	9:15	10:27	72	-1	3	16	12	2	0.88	25	1.56
ST483	5	15	7:36	8:48	72	0	3	16	5	2	0.44	16	1.00

Appendix 8. Con't.

Site	Date: Month	Date: Day	Dive Time: Start	Dive Time: Finish	Dive Time: Minutes	Depth (m): Min	Depth (m): Max	# of Quadrats	Abalone: Measured	Abalone: Not Measured	Abalone: Density (m^{-2})	Urchins: Count	Urchins: Density (m^{-2})
Simonds Group													
SI02	5	7	15:13	16:22	69	-1	4	16	95	2	6.06	177	11.06
SI03	5	7	14:47	16:45	118	-1	2	16	91	0	5.69	157	9.81
SI05	5	7	8:28	9:53	85	2	7	16	44	2	2.88	29	1.81
SI09	5	7	8:16	9:22	66	0	5	16	61	16	4.81	39	2.44
SI16	5	7	11:45	13:30	105	-1	1	16	38	0	2.38	24	1.50
SI20	5	7	13:10	14:25	75	-1	5	16	59	15	4.63	83	5.19
SI21	5	7	10:37	12:02	85	0	2	16	94	20	7.13	114	7.13
SI30	5	7	10:05	10:55	50	0	4	16	15	12	1.69	103	6.44
Spider Island													
SP05	5	6	14:43	16:00	77	-2	3	16	23	0	1.44	57	3.56
SP08	5	6	8:14	9:20	66	-1	3	16	7	1	0.50	3	0.19
SP17	5	6	14:22	15:23	61	-1	5	16	74	4	4.88	59	3.69
SP32	5	6	10:46	12:02	76	-1	2	16	12	11	1.44	36	2.25
SP33	5	6	12:30	13:34	64	-2	1	16	25	8	2.06	29	1.81
SP34	5	6	12:34	13:50	76	-1	1	16	32	1	2.06	44	2.75
SP35	5	6	9:55	10:41	46	-2	5	16	5	2	0.44	41	2.56
SP36	5	6	8:14	10:06	112	0	3	16	30	20	3.13	57	3.56

Appendix 9. Habitat data from the 2011 Central Coast Abalone index site survey. See DFO (2016) for a description of the methodology and a complete list of substrate and algae codes.

	Substrate			Slope	Canopy			Understory			Turf			Encrusting
Site	1	2	3	%	%	Sp 1	Sp 2	%	Sp 1	Sp 2	%	Sp1	Sp 2	%
North Banks Island														
44	3	1	4	19	0			10	LT	PL	10	RB	AC	80
45	3	5	10	15	5	NT		10	LB	LT	10	AC	RB	90
46	3	10		13	5	NT		10	LT		20	AC	RH	80
47	1	2	3	11	50	NT		50	AL	DL	20	RB	AC	80
48	3	10		10	10	NT		5	AM	PH	30	RB	AC	80
49	3	4		10	70	NT		80	CY	CO	10	UL	RF	60
50	3	7		15	40	MA		90	AF	LA	20	AC	RB	40
51	3	2	10	13	40	MA		100	LB	HE	40	RH	AC	40
52	3	1		19	80	NT		90	CY	CO	20	GH	UL	90
53	3	4	10	8	0			0			10	AC	UL	80
Oswald Bay														
38	3	4	10	17	20	MA		90	AF	LS	30	UL		40
39	1	3	2	34	0			5	AM	CO	10	UL	FU	100
40	3	4	6	8	50	NT		50	LB	AM	30	UL	AC	50
41	3	4	10	6	5	NT		5	LT	AL	10	AC	RH	80
42	2	3		27	10	NT		30	AM	CO	10	AC		80
43	3	4	10	23	10	NT		100	CY	DL	15	UL	AC	80
43A	3	10		27	10	NT		70	CO	LT	40	AC	UL	80
Pemberton Bay														
33	3	2	4	17	10	NT		10	AF	CO	20	AC		50
34	2	10	1	36	0			10	LT	PL	15	AC	RF	95
35	2	10		23	0			20	PL	LT	20	AC		80
36	3	4	5	10	5	NT		90	LT	PL	10	AC	RF	70
Lotbiniere Bay														
21	4	3	5	4	40	NT		80	LT	AM	10	DL	AC	40
22	5	3		10	70	NT		90	LT	CY	20	BF	AC	60
23	3	2	4	13	10	NT		100	LT	PH	70	AC	BF	80
24	3	4	7	8	10	MA		40	PT	PH	20	AC	RB	40
25	3	5	4	8	10	NT		90	LT	PL	60	AC	BH	70
27	3	5	4	6	20	NT		95	LT	PL	20	AC	DL	70
28	2			11	0			10	AM	DM	40	UL	RF	80
29	2			29	30	NT		30	DL	AL	10	AC	UL	80
30	3	4		15	30	NT		50	PT	PH	20	AC	RB	70

Appendix 9. Con't.

	Substrate			Slope	Canopy			Understory			Turf			Encrusting
Site	1	2	3	%	%	Sp1	Sp2	%	Sp1	Sp2	%	Sp1	Sp2	%
North Aristazabal Island														
13	3	2	4	27	30	MA		25	LT	CO	10	AC		70
14	3	2	4	25	0			5	LT	CO	20	AC	RH	60
15	2	3	4	13	0			5	DV	AF	30	AC		95
15A	2	3	10	17	0			10	LT	CO	20	AC		80
16	3	2	4	8	40	MA		10	LT	AG	20	AC		20
16A	2	3	4	15	40	NT		40	CO	DV	30	BH	RB	30
17	2	1		19	0			0			5	AC		90
18	1			19	0			10	PH	CO	20	AC	RB	100
19	3	2	4	8	10	EG		20	LT		20	AC	GH	70
20	2	3	4	17	5	EG		10	LT	CO	10	AC	GH	70
South Aristazabal Island														
2	2	3		11	0			10	AM	DL	10	AC	RB	90
3	3	4		10	10	NT		10	CO	AM	10	UL	RB	90
4	3	4	7	15	10	EG		5	GH		25	AC	DL	80
5	2	1		25	0			10	AM	CO	20	BH	AC	90
6	3	2	1	25	10	NT		40	CO	DL	30	AC	CF	80
7	1	2		27	0			10	DL	CO	10	AC	RB	80
8	1	4	3	15	5	NT	EG	10	AM	CO	5	BH	UL	90
9	3	4	5	6	30	MA		10	LB		10	AC	GH	70
10	2	3	1	21	80	NT		90	AL		20	RH	AC	90
10A	3	2		13	10	NT		70	AM	CO	20	AC	GH	80
11	1	2		36	5	NT		20	AM	CO	20	RB	AC	90
12	2	1	3	23	30	NT	EG	5	AL	NT	5	RH	AC	90
Stryker Island														
ST121	2	3		15	20	NT		90	AL	CO	25	AC	RB	40
ST190	2	1		42	20	NT	MA	40	LT	PT	40	RF	RB	60
ST220	2	3		10	5	MA	NT	80	LT	CO	80	AC	DL	90
ST304	2	1		27	5	NT		80	LT	PT	10	AC	RF	80
ST359	2			32	10	MA		40	AG		10	AC		80
ST411	2	1		30	5	NT		100	LT	AL	25	AC	RH	80
ST444	2			34	5	NT		75	LT	LS	50	RH	AC	80
ST483	2	1		27	20	NT		70	LT	DL	60	RF	RB	40

Appendix 9. Con't.

Site	Substrate 1	Substrate 2	Substrate 3	Slope %	Canopy %	Canopy Sp 1	Canopy Sp 2	Understory %	Understory Sp 1	Understory Sp 2	Turf %	Turf Sp 1	Turf Sp 2	Encrusting %
Simonds Group														
SI02	3	1		36	20	NT	EG	100	LT	CO	30	AC	RF	90
SI03	3	10		23	20	NT		100	LT	CY	5	AC	RF	85
SI05	3	2		15	50	MA	NT	100	CO	AM	50	AC		60
SI09	2			30	5	NT		30	LT	DL	20	RF	AC	80
SI16	3	4	10	13	60	MA		40	LS	CY	20	AC		60
SI20	3			25	70	NT		100	PT	CO	40	DY	RF	60
SI21	3	2	4	19	10	NT		100	PT	LT	5	RF	RB	80
SI30	1	2	3	17	70	NT		100	CO	LT	50	RB	AC	60
Spider Island														
SP05	3	1	2	32	50	MA		40	AF		20	AC	GH	80
SP08	2	1		32	60	MA		20	LS	CO	10	BF		60
SP17	2	1		40	20	NT		70	LT	LB	10	RF	BF	90
SP32	2	3		10	10	NT		100	LT	CO	25	RB	AC	100
SP33	2	3		23	20	NT		100	AM	PT	10	AC		70
SP34	1	2		25	10	NT		70	LT	CO	20	RF	AC	70
SP35	2	1		29	0			10	LT	CO	15	AC		80
SP36	3			19	80	NT		80	LB	CO	10	BF	AC	90

Appendix 10. Habitat data from the 2016 Central Coast Abalone index site survey. See DFO (2016) for a description of the methodology and a complete list of substrate and algae codes.

	Substrate			Slope	Canopy			Understory			Turf			Encrusting
Site	1	2	3	%	%	Sp 1	Sp 2	%	Sp 1	Sp 2	%	Sp 1	Sp 2	%
North Banks Island														
44	2	3		21	0			0			2	AC		80
45	3	4		10	1	NT		0			1	AC		80
46	1	2	3	19	0			10	PH		5	AC	RB	80
47	3	4		4	0			0			0	AC		90
48	1	3	4	10	5	NT		5	PL	LT	5	AC		90
49	2	3	4	11	5	NT		10	DM	CO	5	UL	AC	50
50	3	7		13	0			40	HE	LT	30	AC	UL	80
51	3	7		17	50	MA		90	AF	LS	20	AC	RF	80
52	2	3	7	30	1	NT		5	AM	DM	1	UL	AC	40
53	2	4		10	0			10	PH	PL	20	AC	RH	80
Oswald Bay														
38	1	3		19	40	MA		50	LT	DL	50	UL	AC	60
39	1	5		17	0			0			30	AC	LE	70
40	3	5		6	70	MA		50	LB	LT	60	AC	RB	80
41	1	10		13	0			10	PH	PL	1	AC		90
42	2	3	4	17	0			10	PH	DM	20	AC		80
43	3	4	7	13	0			0			1	AC	UL	40
Pemberton Bay														
33	1			17	0			40	RH		40	AC		90
34	2	2	3	13	0			10	LB	NT	20	AC	CS	80
35	3			10	40	PH	AL	20	RH		40	AC		70
36	3	4		13	0			20	LT	PL	10	AC	CS	90
83-37	1	3		23	30	AL	LT	0			30	RF	AC	80
Lotbiniere Bay														
21	2	3	4	10	1	NT		10	DV	CY	20	UL	RB	80
22	3	4	5	4	70	MA	NT	100	DV	DA	30	AC	CO	30
23	2	3	4	21	0			10	PH	PL	15	AC		90
24	3	4	5	10	0			0			5	AC	RH	80
25	3	4	7	8	5	NT		40	PL	LT	50	AC	CS	50
27	2	3	4	11	10	NT		30	DV	DM	10	AC		0
28	2			10	0			1	DV		10	RH	UL	100
29	1			25	0			0			30	AC	RF	95
30	2	3	4	15	0			10	LS	LT	30	AC	CS	70
83-31	2	3	4	13	0			10	PL	LT	10	AC	BH	70
83-32	2	3	4	15	80	NT		90	CY	DL	10	AC	RF	80

Appendix 10. Con't.

	Substrate			Slope	Canopy			Understory			Turf			Encrusting
Site	1	2	3	%	%	Sp 1	Sp 2	%	Sp 1	Sp 2	%	Sp 1	Sp 2	%
North Aristazabal Island														
13	2	1	10	17	0			1	AB		80	AC	CS	60
14	2	3	4	27	0			0			30	AC	BH	80
15	2	3	4	25	0			60	PH	LT	40	AC	FU	40
15A	1	4		11	60	EG	NT	80	AM	HE	80	AC	FU	50
16	2	10		10	30	MA		10	LT		80	AC	CS	10
16A	2	3	7	11	0			40	DV		60	BH		70
17	2	10		10	0			0			1	AC		50
18	2	3	4	29	0			0			1	AC		50
19	1	7		13	0			30	DV		40	AC		80
20	3	3	2	19	5	MA	EG	0			5	AC		90
South Aristazabal Island														
02	2	3	4	21	0			1	CF		20	AC		40
03	1	2	3	19	0			10	CO	DM	10	AC	RF	80
04	4			13	0			0			25	DB	AC	70
05	2	2	3	21	1	NT		5	CO	AM	5	DB	CP	80
06				27	0			5	LT	AM	5	AC	DB	80
07	2			21	0			1	LT	AB	20	AC		90
08	2	3	4	21	0			1	EG		1	AM		70
09	2	3	4	13	50	MA		10	EG	FV	30	AC		30
10				17	0			90	PT	LO	60	AC	DL	50
10A	2	3	4	21	70	NT		60	CO	AM	60	DL	AC	80
11	2	1	3	23	0			0			5	AC	DV	90
12	3			29	0			0			5	AC	DB	80
Stryker Island														
ST121	2	10	3	17	70	MA		70	PT		10	AC	RF	70
ST190	2			27	70	PT		30	AL	RB	20	AC	CS	70
ST220	3	1		15	70	MA		80	PT	AL	80	AC	CS	80
ST304	2	3	4	30	0			70	PT	LT	20	AC		80
ST359	1	3		34	1	MA		1	AB	DV	10	AC	CP	40
ST411	2	3		36	0			30	LS	PL	40	CS	RF	60
ST444	2			21	0			60	LT	NT	70	AC	RF	70
ST483	2			17	0			80	LO	LT	70	AC	RF	10

Appendix 10. Con't.

Site	Substrate 1	Substrate 2	Substrate 3	Slope %	Canopy %	Canopy Sp 1	Canopy Sp 2	Understory %	Understory Sp 1	Understory Sp 2	Turf %	Turf Sp 1	Turf Sp 2	Encrusting %
Simonds Group														
SI02	3	7		32	1	MA		20	LS	DL	20	AC	RF	80
SI03	3	7	10	21	30	MA		15	LB		25	AC	RF	95
SI05	2	3	4	29	50	MA		30	LS	MA	30	AC	RF	80
SI09	2			30	60	PT	NT	50	CF	LT	80	AC	CS	80
SI16	3	4	7	25	10	MA		20	HE	LS	40	AC	CF	70
SI20	2	3		32	10	PT		40	PT	NT	30	BF	AC	80
SI21	2	3		19	10	PT		70	PT	LT	30	AC	RF	80
SI30	2	3		17	60	PT		70	PH	AL	80	AC		70
Spider Island														
SP05	3	1	10	34	10	MA		1	AF		5	AC	LE	15
SP08	1	10		23	30	MA		20	MA	AF	30	UL	AC	75
SP17	1	2	3	38	5	MA		40	LT	PL	20	AC	RF	80
SP32	2	3	4	19	0			70	LT	LO	70	AC	RF	20
SP33	1	3		23	60	PT	LT	60	PH	DM	70	AC	RB	70
SP34	2			13	1	MA		50	LT	DM	60	AC	RF	70
SP35	1			38	40	LH	PH	30	NT	DL	70	AC	CS	80
SP36	3	4	1	17	10	NT		60	LT	LS	30	AC	NT	90

Appendix 11. Dive Summary from the 2014 Queen Charlotte Strait Northern Abalone index site survey.

	Date		Dive Time			Depth (m)			Abalone			Urchins	
Site	Month	Day	Start	Finish	Minutes	Min	Max	# of Quadrats	Measured	Not Measured	Density (m^{-2})	Count	Density (m^{-2})
Gordon Channel													
I01	5	25	10:51	12:02	71	0	3	12	8	0	0.67	63	5.25
I02	5	25	12:43	13:52	69	-1	4	16	1	0	0.06	18	1.13
I03	5	25	10:35	11:58	83	-3	1	16	0	0	0.00	7	0.44
I04	5	25	12:20	13:00	40	-3	2	16	1	0	0.06	31	1.94
I05	5	26	12:35	13:38	63	4	7	16	8	0	0.50	128	8.00
I06	5	26	10:10	11:27	77	-1	3	12	0	0	0.00	16	1.33
R02	5	25	15:14	16:40	86	0	2	16	5	0	0.31	8	0.50
R03	5	25	9:07	10:25	78	-1	5	16	3	0	0.19	33	2.06
R04	5	26	11:53	12:40	47	-2	2	16	0	0	0.00	0	0.00
R06	5	26	14:28	15:33	65	0	2	14	2	0	0.14	7	0.50
R07	5	26	10:28	11:55	87	0	1	16	1	0	0.06	29	1.81
R10	5	25	9:14	10:00	46	0	5	16	0	0	0.00	30	1.88
R11	5	26	13:26	14:48	82	-2	1	16	0	0	0.00	0	0.00
R12	5	26	14:11	15:29	78	0	2	16	3	0	0.19	25	1.56
R15	5	26	8:35	9:55	80	-1	3	16	3	0	0.19	33	2.06
R19	5	26	8:42	9:37	55	-1	4	16	2	0	0.13	29	1.81
R20	5	25	15:06	16:00	54	-1	6	16	0	0	0.00	8	0.50
North Queen Charlotte Strait													
R29	5	24	13:48	14:41	53	0	4	16	1	0	0.06	12	0.75
R30	5	23	9:13	10:20	67	-2	0	16	1	0	0.06	1	0.06
R31	5	24	8:54	9:35	41	-3	2	16	0	0	0.00	0	0.00
R33	5	23	13:25	14:36	71	2	6	14	0	0	0.00	18	1.29
R35	5	24	14:11	15:23	72	-1	6	16	0	0	0.00	30	1.88
R36	5	23	15:14	16:34	80	0	4	16	0	0	0.00	42	2.63
R37	5	23	13:16	14:29	73	-1	0	16	0	0	0.00	13	0.81
R39	5	24	8:47	9:40	53	-1	4	12	4	0	0.33	31	2.58
R47	5	23	12:11	13:00	49	-1	5	16	0	0	0.00	13	0.81
R48	5	24	10:09	11:13	64	-2	3	16	0	0	0.00	27	1.69
R49	5	23	9:43	11:33	110	-1	6	16	3	0	0.19	11	0.69
R53	5	23	16:27	17:17	50	-1	2	16	1	0	0.06	6	0.38
R54	5	24	10:07	11:19	72	-2	4	16	0	0	0.00	17	1.06
R57	5	23	11:17	12:09	52	-2	3	16	0	0	0.00	2	0.13

Appendix 12. Habitat data from the 2014 Queen Charlotte Strait Abalone index site survey. See DFO (2016) for a description of the methodology and a complete list of substrate and algae codes.

	Substrate			Slope	Canopy			Understory			Turf			Encrusting
Site	1	2	3	%	%	Sp 1	Sp 2	%	Sp 1	Sp 2	%	Sp 1	Sp 2	%
Gordon Channel														
I01	1	2	3	25	5	NT	EG	90	LB	PT	5	AC	RB	90
I02	1	2		30	10	NT	EG	60	CY	CO	10	DL	IR	80
I03	1	2	3	29	20	NT		100	PT	DL	30	AC	RB	70
I04	2	3	10	32	70	NT		80	CY	DV	20	UL	AC	0
I05	2	1		19	80	NT		80	DV	DL	10	AC	OP	90
I06	2	3	10	43	90	NT		100	CY	DV	40	UL	AC	30
R02	2			15	100	PT	LT	15	DM	LS	20	DL	AC	80
R03	2			36	10	NT		90	DM	CO	30	AC	DL	70
R04	2	4	10	25	40	MA	NT	90	CY	CO	20	AC	RF	50
R06	2	4		15	0			0			0			0
R07	3	4		6	50	NT		100	CY	DV	30	AC	DV	80
R10	2	10		32	40	NT		70	CY	DM	10	AC	DM	70
R11	1	2	3	15	30	EG	NT	100	DV	AM	70	AC	RF	60
R12	2	4		11	30	MA	NT	100	CY	CO	10	AC	DL	80
R15	3	4	1	23	5	NT		90	DM	DV	20	UL	GI	80
R19	2	10		29	40	NT		79	CY	LS	20	AC	LS	60
R20	2	10		40	40	NT		80	CY	DM	20	AC	RB	80
North Queen Charlotte Strait														
R29	10	3	1	23	10	NT	PT	80	LT	LS	20	AC	RB	80
R30	10	2		13	30	MA	EG	70	PL	LB	90	AC		0
R31	10	2	3	30	10	EG		90	PL	AM	20	AC	UL	40
R33	1			33	0			50	DL	DV	50	DL	DV	40
R35	2	1		38	0			80	PH	AA	50	AC	FA	85
R36	1	3	10	25	90	NT		70	CO	CY	15	AC		70
R37	2	3	10	10	20	NT		70	DV	CY	30	AC	UL	60
R39	2			41	0			90	PL	LT	50	AC	CN	95
R47	1	2	10	38	0			25	LT	PL	10	AC	RB	70
R48	2			32	30	NT		80	LB	AB	20	RF	UL	0
R49	2	3		36	25	NT	PT	50	LB	CO	25	AC	RB	75
R53	2	3		19	30	NT		70	LB	CY	40	AC	RB	60
R54	2	3		34	50	NT		80	LB	CY	20	AC	OP	70
R57	7	10	2	30	20	MA		50	PT	CY	30	AC	RB	30

Appendix 13. Dive Summary from the 2008 West Coast Vancouver Island Northern Abalone index site survey. Sites that were sampled in 2003, 2008, and 2013 are indicated with an "*".

	Date		Dive Time			Depth (m)			Abalone			Urchins	
Site	Month	Day	Start	Finish	Minutes	Min	Max	# of Quadrats	Measured	Not Measured	Density (m^{-2})	Count	Density (m^{-2})
Quatsino Sound													
Q01*	5	21	10:28	11:20	52	2	4	16	3	1	0.25	2	0.13
Q04*	5	22	9:14	10:48	94	2	6	16	4	0	0.25	1	0.06
Q05*	5	21	8:41	10:03	82	1	4	16	3	0	0.19	0	0.00
Q09*	5	22	8:40	9:46	66	1	5	16	1	0	0.06	1	0.06
Q10*	5	22	13:11	14:12	61	0	5	16	4	0	0.25	0	0.00
Q12*	5	22	8:48	9:45	57	1	4	16	2	0	0.13	0	0.00
Q13*	5	22	15:45	16:35	50	1	4	16	3	0	0.19	1	0.06
Q24*	5	22	14:54	15:25	31	0	2	8	0	0	0.00	0	0.00
Q25*	5	21	13:27	14:08	41	-1	2	8	0	0	0.00	2	0.25
Q46*	5	21	14:47	15:50	63	4	6	16	4	0	0.25	2	0.13
Q47*	5	22	10:30	11:11	41	2	6	16	7	0	0.44	1	0.06
Brooks Bay													
B11*	5	23	10:33	11:02	29	1	4	8	0	0	0.00	0	0.00
B15*	5	23	13:12	13:46	34	0	3	8	0	0	0.00	0	0.00
B19*	5	23	14:17	14:49	32	0	5	8	0	0	0.00	2	0.25
B26*	5	23	15:01	15:26	25	1	4	8	0	0	0.00	0	0.00
B50*	5	23	13:38	14:27	49	1	5	16	10	0	0.63	0	0.00
B51	5	24	10:31	10:51	20	3	5	8	0	0	0.00	0	0.00
B52	5	24	10:07	11:22	75	2	5	16	2	0	0.13	4	0.25
B55	5	24	8:43	9:27	44	1	2	8	0	0	0.00	0	0.00
B60	5	24	8:43	9:45	62	2	5	16	2	2	0.25	0	0.00
B62	5	23	10:34	10:56	22	2	5	8	0	0	0.00	0	0.00
B64	5	24	13:15	13:26	11	0	2	8	0	0	0.00	0	0.00
B69	5	24	13:50	14:14	24	0	5	8	0	0	0.00	0	0.00

Appendix 14. Dive Summary from the 2013 West Coast Vancouver Island Northern Abalone index site survey.

	Date		Dive Time			Depth (m)			Abalone			Urchins	
Site	Month	Day	Start	Finish	Minutes	Min	Max	# of Quadrats	Measured	Not Measured	Density (m^{-2})	Count	Density (m^{-2})
Quatsino Sound													
Q01	5	17	10:32	11:35	63	1	3	16	4	0	0.25	3	0.19
Q02	5	17	8:44	9:56	72	1	6	16	2	0	0.13	4	0.25
Q03	5	16	13:12	14:34	82	4	9	16	0	0	0.00	3	0.19
Q04	5	16	13:27	14:45	78	3	5	16	2	0	0.13	1	0.06
Q05	5	17	8:36	10:05	89	0	2	16	2	0	0.13	0	0.00
Q06	5	17	14:18	15:15	57	4	6	16	2	0	0.13	6	0.38
Q07	5	16	9:22	9:49	27	2	4	8	0	0	0.00	1	0.13
Q08	5	16	15:28	15:55	27	3	5	8	0	0	0.00	1	0.13
Q09	5	16	8:08	8:39	31	0	3	8	0	0	0.00	0	0.00
Q10	5	16	10:17	11:23	66	2	7	16	1	0	0.06	0	0.00
Q12	5	17	13:20	14:31	71	2	5	16	2	0	0.13	12	0.75
Q13	5	16	9:11	9:59	48	1	4	16	0	0	0.00	5	0.31
Q14	5	17	10:59	11:28	29	2	6	7	0	0	0.00	0	0.00
Q16	5	17	12:05	12:37	32	5	7	8	0	0	0.00	1	0.13
Q24	5	16	8:28	9:00	32	0	1	8	0	0	0.00	0	0.00
Q25	5	16	15:06	15:58	52	1	2	16	0	0	0.00	1	0.06
Q46	5	16	10:27	11:25	58	2	7	16	2	0	0.13	2	0.13
Q47	5	17	12:00	12:43	43	2	6	16	1	0	0.06	3	0.19
Brooks Bay													
B11	5	19	10:55	11:40	45	2	5	8	0	0	0.00	1	0.13
B15	5	19	8:37	9:20	43	1	4	8	0	0	0.00	0	0.00
B19	5	19	9:37	10:26	49	2	5	8	0	0	0.00	1	0.13
B26	5	18	14:12	14:33	21	2	8	8	0	0	0.00	0	0.00
B50	5	18	12:33	13:49	76	1	6	16	2	0	0.13	0	0.00
B51	5	18	8:37	9:11	34	3	5	8	0	0	0.00	2	0.25
B52	5	18	8:10	9:25	75	1	5	16	1	0	0.06	4	0.25
B55	5	18	9:51	10:43	52	1	4	16	4	0	0.25	0	0.00
B56	5	18	9:36	10:15	39	0	1	8	0	0	0.00	0	0.00
B60	5	18	10:39	11:51	72	1	7	16	4	0	0.25	11	0.69
B61	5	19	10:52	12:10	78	2	7	16	1	0	0.06	5	0.31
B62	5	18	11:49	12:46	57	0	5	16	3	0	0.19	0	0.00
B69	5	18	15:57	16:49	52	0	4	16	1	0	0.06	0	0.00
B71	5	19	8:20	8:53	33	0	3	8	0	0	0.00	1	0.13
B72	5	19	9:29	10:29	60	0	4	16	3	0	0.19	1	0.06
B73	5	18	14:45	15:36	51	2	10	16	3	0	0.19	2	0.13

Appendix 14. Con't.

	Date		Dive Time			Depth (m)			Abalone			Urchins	
Site	Month	Day	Start	Finish	Minutes	Min	Max	# of Quadrats	Measured	Not Measured	Density (m^{-2})	Count	Density (m^{-2})
Checleset Bay													
C01	5	21	8:49	10:03	74	0	2	16	2	0	0.13	3	0.19
C08	5	21	13:20	14:36	76	0	2	16	7	0	0.44	5	0.31
C09	5	20	11:00	12:24	84	1	7	16	1	0	0.06	1	0.06
C10	5	21	13:38	14:48	70	1	8	16	3	0	0.19	0	0.00
C14	5	20	10:26	11:30	64	-1	2	16	1	0	0.06	0	0.00
C15	5	20	15:30	16:34	64	0	2	16	1	0	0.06	0	0.00
C19	5	20	8:55	9:17	22	0	2	8	0	0	0.00	0	0.00
C21	5	20	14:10	15:15	65	0	7	16	3	0	0.19	1	0.06
C22	5	20	9:42	10:11	29	2	6	8	0	0	0.00	0	0.00
C27	5	20	15:45	16:40	55	1	6	16	6	0	0.38	0	0.00
C29	5	21	10:33	12:04	91	0	4	16	3	0	0.19	5	0.31
C32	5	21	9:25	9:52	27	-1	4	8	0	0	0.00	0	0.00
C34	5	21	11:20	12:16	56	2	6	8	0	0	0.00	2	0.25
C35	5	21	13:28	14:24	56	4	6	16	3	0	0.19	0	0.00
C41	5	21	9:48	10:57	69	1	5	16	3	0	0.19	0	0.00
C43	5	20	12:08	12:51	43	-2	3	16	0	0	0.00	0	0.00
C45	5	21	8:20	9:25	65	0	5	16	5	0	0.31	5	0.31
C46	5	20	8:47	9:17	30	0	1	8	0	0	0.00	0	0.00
Kyuquot Sound													
K06	5	22	10:06	11:30	84	0	5	16	7	1	0.50	13	0.81
K07	5	21	15:24	16:22	58	0	4	16	3	0	0.19	2	0.13
K12	5	22	8:30	9:44	74	2	8	16	3	0	0.19	18	1.13
K17	5	22	14:12	15:32	80	2	6	16	7	0	0.44	7	0.44
K25	5	22	13:28	13:56	28	0	2	8	0	0	0.00	3	0.38
K26	5	22	14:31	15:13	42	1	4	8	0	0	0.00	1	0.13
K31	5	22	8:46	9:53	67	4	7	16	3	0	0.19	3	0.19
K47	5	21	16:07	16:38	31	2	4	8	0	0	0.00	1	0.13
K49	5	22	10:40	11:56	76	1	5	16	9	0	0.56	25	1.56
K50	5	22	13:23	13:43	20	2	7	8	0	0	0.00	0	0.00

Appendix 15. Habitat data from the 2008 West Coast Vancouver Island Abalone index site survey. See DFO (2016) for a description of the methodology and a complete list of substrate and algae codes.

	Substrate			Slope	Canopy			Understory			Turf			Encrusting
Site	1	2	3	%	%	Sp 1	Sp 2	%	Sp 1	Sp 2	%	Sp 1	Sp 2	%
Quatsino Sound														
Q01	3	4	10	15	60	MA		50	PT	MA	30	RB	BF	70
Q04	3	4		21	40	NT	PT	80	AA	PT	70	RF	RH	20
Q05	4	10	3	17	80	MA		40	MA	LS	30	RB	AC	40
Q09	4	7	3	25	80	MA		80	AF	LS	10	GI	RF	40
Q10	2	3	4	32	80	MA		80	AF	LS	40	AC	RF	50
Q12	2	3	4	21	90	MA	PT	70	PT	DL	70	RF	RH	40
Q13	2	3	4	23	70	MA		80	PT	AG	15	AC		70
Q24	3	4	10	23	50	MA		80	AF	LS	15	AC		60
Q25	1	3	4	30	10	NT		80	PT	DL	70	RF	RB	40
Q46	1	2	3	15	0			80	PT	LA	5	RF	DY	80
Q47	2			23	0			60	PT	LT	80	RH	RF	30
Brooks Bay														
B11	1	10	4	46	50	MA		50	AF	MA	10	AC	BH	20
B15	1	5	10	34	20	MA	NT	80	PH	PT	40	AC	RF	30
B19	1	2	3	57	0			75	PH	DE	80	AC	RF	30
B26	2	10	11	42	90	MA		40	PT	DL	40	AC	RF	80
B50	2	1	3	29	90	MA		5	AF	DL	80	AC		80
B51	2	1	3	27	60	PT	NT	80	NT	DL	70	RF	BF	30
B52	3	4		19	40	MA	NT	70	PT	CO	50	DY	AC	30
B55	3	4	5	15	70	MA		30	MA		50	CR	GI	40
B60	2	3		19	60	MA	NT	80	DL	PT	60	RF	RH	50
B62	2	3	4	27	90	PT	MA	30	DL	LT	90	RF		20
B64	1	2	10	30	10	MA		25	ZO	DL	20	AC	RB	20
B69	2	10	11	65	80	MA		90	AF	LS	10	AC		40

Appendix 16. Habitat data from the 2013 West Coast Vancouver Island Abalone index site survey. See DFO (2016) for a description of the methodology and a complete list of substrate and algae codes.

	Substrate			Slope	Canopy			Understory			Turf			Encrusting
Site	**1**	**2**	**3**	**%**	**%**	**Sp 1**	**Sp 2**	**%**	**Sp 1**	**Sp 2**	**%**	**Sp 1**	**Sp 2**	**%**
Quatsino Sound														
Q01	3	4	10	15	60	MA		50	PT	MA	30	RB	BF	70
Q04	3	4		21	40	NT	PT	80	AA	PT	70	RF	RH	20
Q05	4	10	3	17	80	MA		40	MA	LS	30	RB	AC	40
Q09	4	7	3	25	80	MA		80	AF	LS	10	GI	RF	40
Q10	2	3	4	32	80	MA		80	AF	LS	40	AC	RF	50
Q12	2	3	4	21	90	MA	PT	70	PT	DL	70	RF	RH	40
Q13	2	3	4	23	70	MA		80	PT	AG	15	AC		70
Q24	3	4	10	23	50	MA		80	AF	LS	15	AC		60
Q25	1	3	4	30	10	NT		80	PT	DL	70	RF	RB	40
Q46	1	2	3	15	0			80	PT	LA	5	RF	DY	80
Q47	2			23	0			60	PT	LT	80	RH	RF	30
Brooks Bay														
B11	1	10	4	46	50	MA		50	AF	MA	10	AC	BH	20
B15	1	5	10	34	20	MA	NT	80	PH	PT	40	AC	RF	30
B19	1	2	3	57	0			75	PH	DE	80	AC	RF	30
B26	2	10	11	42	90	MA		40	PT	DL	40	AC	RF	80
B50	2	1	3	29	90	MA		5	AF	DL	80	AC		80
B51	2	1	3	27	60	PT	NT	80	NT	DL	70	RF	BF	30
B52	3	4		19	40	MA	NT	70	PT	CO	50	DY	AC	30
B55	3	4	5	15	70	MA		30	MA		50	CR	GI	40
B60	2	3		19	60	MA	NT	80	DL	PT	60	RF	RH	50
B62	2	3	4	27	90	PT	MA	30	DL	LT	90	RF		20
B64	1	2	10	30	10	MA		25	ZO	DL	20	AC	RB	20
B69	2	10	11	65	80	MA		90	AF	LS	10	AC		40

Appendix 16. Con't.

	Substrate			Slope	Canopy			Understory			Turf			Encrusting
Site	**1**	**2**	**3**	**%**	**%**	**Sp 1**	**Sp 2**	**%**	**Sp 1**	**Sp 2**	**%**	**Sp 1**	**Sp 2**	**%**
Checleset Bay														
C01	2	3	4	34	0			40	AG	PT	40	AC		50
C08	2	3		10	30	MA		80	PT		10	AC	RF	80
C09	3	4		17	30	MA		50	PT	LT	20	RF	AC	80
C10	2	10		38	30	PT	MA	60	PT		30	AC	DE	50
C14	2	3	4	17	50	MA	PT	10	PT	LB	40	RF	AC	30
C15	3	4		10	80	MA		50	PT		30	RF	AC	75
C19	2	3	7	23	0	0		50	DM	GI	5	AC		30
C21	2	7	10	40	50	MA		40	AG	PT	0			90
C22	1	3		46	30	MA		30	PT	LB	20	RF	AC	80
C27	2			32	80	MA		20	PT		30	AC		80
C29	2	3	10	23	30	MA	PT	60	PT	LB	40	AC		50
C32	10	3	2	50	50	MA		25	AF		20	RH	AC	30
C34	1	2	3	53	30	MA		30	PT	LT	15	RF	AC	90
C35	2	3	4	13	40	MA		20	AG	DE	30	RF	AC	20
C41	3	4	7	27	50	MA		60	PT	LB	20	AC		80
C43	2	1	3	27	40	MA		10	AF		60	AC	GB	20
C45	2	3		30	40	MA		60	AF	LS	60	AC		80
C46	4	3	1	15	60	MA		60	AF	LB	10	AC	RF	60
Kyuquot Sound														
K06	1	3	4	29	50	MA		60	PT	AF	20	AC	RF	60
K07	2	3	4	23	50	MA		30	PT		10	RB	DM	70
K12	1	2	3	30	0			50	AF		60	RB	AC	60
K17	2	3		25	80	MA	PT	10	PT	AF	5	AC		50
K25	2	1		27	30	MA		70	EI	PT	10	AC		90
K26	1	2	4	34	30	MA		70	PT	LT	10	RF	AC	80
K31	1	2	3	15	5	NT		20	PT	NT	15	DM	RF	80
K47	7	1		27	80	MA		0			20	RF	RB	60
K49	2	3	4	27	60	MA		75	PT	EI	5	AC		80
K50	2	7		57	50	MA		20	AF	LS	30	RF	RB	60