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Review of Status of Northern, or Pinto, Abalone, *Haliotis Kamtschatkana*, in Canada

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Abstract

Jamieson (1989) reviewed the status of northern, or pinto, abalone (*Haliotis kamtschatkana*) in British Columbia, Canada, but while the paper was accepted and reviewed by COSEWIC in April, 1988, no status could be assigned, as at that time COSEWIC had no mandate for invertebrates. COSEWIC's mandate changed in 1994, however, and COSEWIC is now able to assign status to molluscs. Here, I update the review of the status of this species in relation to recognised threats which might lead to this species' extirpation in Canada. Threats are identifiable, but the risks of population extinction associated with them are impossible to quantify. For example, natural northern abalone population size and size frequency structure equilibria are unknown (recent prefishery levels may have been high because of earlier abalone predator (sea otter) extirpation); unquantifiable but possibly substantial continued illegal northern abalone harvest in British Columbia, even though all northern abalone fisheries have been closed since 1990; and an unknown overall spatial abundance distribution, with time-series abundance data only available from a limited number (53) of index sites. Nevertheless, available data indicate continued declining abundance following fishery closure, and as sea otters slowly expand their range, natural mortality rate of northern abalone in areas where sea otters do not now occur will increase. Biological data suggests that the absolute abundance of adult abalone in close proximity to each other affects spawning success (external gamete fertilisation), and that larval dispersal range from concentrations of abalone may be quite limited. Individual concentrations of abalone may thus be largely self-sustaining, and potentially vulnerable to local extirpation over time if they experience a sustained high adult mortality. Monitoring of index sites, where abalone previously occurred, shows an increased frequency of sites which have no abalone now.

Résumé

Jamieson (1989) a fait un examen du statut de l'ormeau nordique (*Haliotis kamtschatkana*) en Colombie-Britannique (Canada) et bien que sa publication ait été acceptée et examinée par le COSEWIC en avril 1988, aucun statut n'a été assigné, les invertébrés ne faisant pas partie du mandat du COSEWIC. Le mandat du Comité a cependant été modifié en 1994 et ce dernier est donc en mesure d'assigner un statut aux mollusques. Dans ce document, on présente une mise à jour de l'examen du statut de cette espèce dans le contexte des menaces connues qui pourraient donner lieu à sa disparition au Canada. Ces menaces peuvent être identifiées, mais les risques d'une disparition de la population qui leurs sont associés ne peuvent être quantifiés. Par exemple, l'équilibre de l'effectif et de la structure de la fréquence des tailles de la population naturelle sont inconnus (l'abondance récente d'avant la pêche pouvait être élevée à cause de la disparition de son prédateur, la loutre de mer), il existe une récolte illégale continue non quantifiable, mais possiblement importante, de l'ormeau nordique en Colombie-Britannique, bien que la pêche de l'ormeau nordique ait été fermée depuis 1990, et la répartition spatiale générale de l'ormeau est inconnue, des séries chronologiques de données d'abondance d'ormeaux n'existent que pour un nombre limité de sites indices (53). Les données actuelles montrent cependant un déclin continu de l'abondance après la fermeture de la pêche et, à mesure que les loutres de mer élargiront leur aire de répartition, la mortalité naturelle des ormeaux augmentera dans les zones où elles ne sont pas encore présentes. Les données biologiques portent à croire que l'abondance absolue des

ormeaux adultes se trouvant à proximité les uns des autres influe sur la réussite de la reproduction (fécondation externe des gamètes) et que l'aire de distribution des larves autour des concentrations d'ormeaux pourrait être passablement limitée. Les concentrations individuelles d'ormeaux pourraient donc être en grande partie auto-suffisantes et potentiellement vulnérables à une mortalité des adultes élevée et constante. Le contrôle des sites indices, déjà occupés par des ormeaux, montre qu'il y a accroissement du nombre de sites où les ormeaux sont absents.

Introduction

The Northern Abalone is the world's northernmost abalone species, and is the only abalone species in Washington State, British Columbia and Alaska, although there are eight species found in the North-east Pacific in California (Cox 1962). McLean (1966) provided the following description for it: "Shell relatively small, thin, elongate-oval, low. Open holes 3 to 6, on tubular projections. Broad channel present on the body whorl between the suture and row of holes. Sculpture of irregular bumps superimposed over spiral sculpture of broad ribs with weak spiral ribs in interspaces. Colour mottled reddish or greenish with areas of white or blue. Shell margin narrow. Muscle scar lacking, interior pearly white with faint iridescence of pink and green." British Columbia specimens differ from Californian specimens in not having a broad channel in the body whorl, a less complex distribution of lumps in the spiral sculpture and the presence of a muscle scar on the anterior of some shells (McLean 1966).

Jamieson (1989) reviewed the status of Northern, or Pinto, Abalone (*Haliotis kamtschatkana*) in British Columbia, Canada, but while the paper was accepted and reviewed by COSEWIC in April, 1988, no status could be assigned as at that time, COSEWIC had no mandate for invertebrates. COSEWIC's mandate changed in 1994, however, and COSEWIC is now able to assign status to molluscs. Here, I review the current status of this species in relation to threats, and describe changes in abundance and fisheries management which have occurred since Jamieson's (1989) earlier report. It should be noted at the onset that concern about the status of northern abalone has been expressed by the Department of Fisheries and Oceans (DFO) since the mid 1980's. Declining indices of abundance resulted in the then unprecedented step of totally closing the northern abalone fishery in 1990. Subsequent surveys, even in the absence of legal fishing, show continued decline in abundance indices. The causes of this continued decline in indexed abundance are not known and can only be speculated on at this time, so evaluation of overall risk of northern abalone disappearance from Canada is impossible to determine except in a general sense.

Distribution

As noted by Sloan and Breen (1988) and Jamieson (1989), the northern abalone is found from Sitka Island, Alaska (57° N; Paul and Paul 1981) to Turtle Bay, Baja California (27.5° N; McLean 1966)). In central California, the typical form merges into the subspecies *H. kamtschatkana assimilis* Dall (Threaded Abalone), which occupies the southern part of the range (McLean 1966). The type locality for *H. kamtschatkana*, "near Unalaska, Kamchatka Sea", is evidently in error since there are no records of *Haliotis* occurring at any point along the Aleutian Islands (McLean 1966). At its northern range limit, northern abalone occur from the lower intertidal zone to at least 100 m depth, whereas near its southern range limit, it is strictly subtidal, with most individuals between 10-20 m depth (McLean 1966). In British Columbia, most of the adult population is found at < 10 m depth (Mottet 1978). Northern Abalone prefer a firm substrate, usually rock, and are generally found in areas of moderate water exchange, such as occurs on exposed or semi-exposed coasts. They are patchily distributed within this habitat.

Habitat

There is no indication that there has been any permanent physical substrate alteration in northern abalone (hence referred to just as abalone) habitat over time. However, macroagal structural species in the nearshore coast habitat are believed to be less abundant now than in the long ago past before extirpation of sea otters (*Enhydra lutris*) over much of the British Columbian coast. Abalone may now be more vulnerable to visual predators, such as humans.

Fluctuation in biotic factors such as food availability and predators appear to vary substantially on a local scale, and catastrophes such as oil spills and human-induced, increased sedimentation can have short-term deleterious consequences. Abalone prefer cool, exposed waters, but in British Columbia, most decreases in marine water quality or disruption of substrate by either industry or urbanisation have occurred in sheltered waters (e.g. harbours), either around estuaries or in the thermally-stratified waters of the Strait of Georgia, where abalone do not occur in abundance. However, eradication of sea otters in the 1800's by their harvest had ecosystem implications which likely affected abalone. Herbivorous prey items of sea otters, notably sea urchins and even abalone, likely subsequently increased in abundance dramatically. This resulted in the establishment of "sea urchin barrens", which are large areas populated with urchins and virtually devoid of marine macroalgae. Sea urchins and abalone often co-occur and may compete for food, and in such food-limited environments, abalone growth may be reduced. Young abalone seem to predominantly feed on bacterial epibiota but larger abalone often feed on pieces of detached, drifting algae, which they capture with their epipodia. Stunted abalone, called "surf" abalone, occur on exposed outer coasts, where again food may be limited because of strong wave action and water currents. Feeding opportunities may be reduced because abalone would be less able to catch and hold on to drift algae. When "surf" abalone are transplanted to calmer kelp-abundant habitats, they commence growing again (Emmett et al. 1988), suggesting that growth rate reduction can be the result of food limitation and that food variability exists in different abalone habitats.

Population Size and Trends

A. Long-term trends: Sloan and Breen (1988) and Jamieson (1989) both described factors influencing the abundance of abalone in British Columbia up until the mid-1980's. Briefly, the suggested relatively high abundance of abalone in the early 1970's (Fig. 1) may have been influenced by the absence at that time of significant abalone fisheries and the earlier extirpation of sea otters. Sea otters are a major predator of abalone, which are a preferred prey (Johnson 1982; Estes and VanBlaricom 1985). In areas where sea otters have been re-introduced in British Columbia, almost all surviving abalone are found only in rock crevices, while outside the range of sea otters, live abalone are abundant outside crevices on open rock faces (Hines and Pearse

1982; Watson 1993). Following eradication of the sea otter, it is hypothesised that abalone populations may have increased substantially in abundance by expanding their distribution to open habitats.

B. Recent fisheries: The modern industrial, i.e. export, abalone fishery began in British Columbia around 1975, and reported annual landings peaked in British Columbia in 1977-78 at around 400 t (Fig. 1), before being reduced by a quota to 226.8 t in 1979 and 113.4 t in 1980. Quotas continued to be reduced in subsequent years, until leveling out at 47.2 t from 1985-89. Any smaller quota, while still maintaing a fishery, was considered impractical at the time, as existing, limited entry fishers stated they would then be unable to make a desirable living, with the only other option being total fishery closure. Recreational and aboriginal fisheries had no quotas, and the quantity of abalone landed by them has never been documented. Because commercial fishery closure would be a precedent setting event and would affect the livelihood of fishers, the closure of abalone fisheries to all user groups, implemented in 1990 for conservation reasons, only occurred after there was wide consensus that abalone populations were not recovering in response to earlier reduced quotas (Farlinger 1990). The legal size limit for abalone was initially four inches shell length, but was reduced to 100 mm when regulations were converted to the metric system.

There has never been commercial fishing for northern abalone in Washington State, and Alaska's limited commercial fishery was closed in 1996. The recreational fishery for abalone in Washington was closed in 1994, also because of conservation concerns. There is currently an Alaskan sport fishery for abalone (minimum legal size = 89 mm (3.5 in)), but abalone cannot be fished with SCUBA gear, meaning harvests are only through snorkelling or handpicking in the intertidal and are therefore limited.

Efforts have continuously been made to manage the BC abalone fishery to a sustainable level of production, but there were little data to indicate what this level might actually be. Abundance of legal-size abalone may have declined by as much as 60-90% by 1978 (Sloan and Breen 1988), the time active abalone management began. At the beginning of 1976, the estimated stock in areas available for harvest was ~1800 t, but it was only ~450 t by the end of 1980 (Breen 1986). Annual production was initially assumed to be substantial because of the large initial biomass, but data from the mid-1980's indicated that annual recruitment was occurring at less that predicted levels (Breen 1980b), raising questions about our whole understanding of factors affecting abalone abundance, and particularly the relative roles of biotic and abiotic factors.

C. Northern Abalone biology:

a) *Reproduction:* Abalone are dioecious, i.e. individuals are of only one sex, and spawning is via the release of gametes into the water, with external fertilisation. Initiation of spawning by one individual typically triggers within a few seconds spawning by near-by individuals. Levitan and Sewell (1998) reviewed how the spatial distribution, abundance and behaviour of spawning individuals influences fertilisation success. Female reproductive success is highly variable, and is largely influenced by the proximity and number of simultaneously spawning males. Fertilisation is therefore maximised when abalone concentrate in abundance during spawning. Abalone can have ripe gonads year round (Quayle 1971), but there is speculation (Sloan and Breen 1988) that “dribble spawning” may occur, with spawning by any individual spread out over a considerable time period. This does not imply that only a relatively few gametes are released at any one time, but that significant periods of spawning activity can occur over the course of a season, with some rebuilding of gonad size between spawnings.

b) *Larval dispersal:* We currently know nothing about the dispersal of larvae from northern abalone populations, but it seems appropriate to assume that this species has larval dispersal characteristics similar to other haliotids. Somewhat unique among exploited marine invertebrates, *Haliotis* species have a particularly short larval period, typically being less than 10 days. Olson (1984) and Calderwood (1985) reported that larval period in hatcheries for northern abalone ranged from 4 to 8 days at 14 to 10° C., respectively. In the early 1980s, it had been generally assumed that free-swimming meroplanktonic larvae dispersed relatively widely (Fedorenko and Sprout 1982). However, Prince et al. (1987) suggested from a simple experiment that *H. rubra* recruitment from a specific population was limited to the immediate vicinity of conspecifics. They hypothesised that dispersal of larvae for this species was generally limited to a scale of <50 m. Prince et al. (1988) conducted a more extensive study to further test this hypothesis, and concluded that larval dispersal for this species could be as small as 10-100 m, and that limited dispersal was indeed the most likely explanation for their observations. In the absence of data specific to northern abalone, it is assumed that northern abalone dispersal is also limited in geographic extent.

c) *Growth and Maturity:* Molluscs are typically aged by growth rings on the outside of their shells, or in the case of bivalves, in their hinge areas. As a gastropod, abalone could only be expected to be aged by growth rings, but because of their shell’s flattened nature, shell wear and its rough texture, this is not possible (Fournier and Breen 1983). However, by tagging individuals in the wild and monitoring size change over time, it has been estimated that age at legal size is about 6-8 years (Qualye 1971, Breen 1986), and that annual growth is about 5-6 mm per year in shell length at recruitment (Sloan and Breen 1988). Average longevity is not known, but growth appear to slow down with age and individuals have been hypothisised to live up to 50 y (Breen 1980a). While 50 % of abalone were estimated to be mature at 55 mm shell length, the importance of large mature female abalone in contributing to total population fecundity had probably until recently been underestimated. For example, at an eastern Moresby Island, B.C., study site in 1990, 20% of mature female abalone were above the legal size of 100 mm shell length, yet these large abalone were estimated to produce 50% of the total potential eggs released by that population (Campbell et al. 1992).

d) *Spatial distribution:* Although abalone occur throughout the outer coastal areas of British Columbia, even when abundant, their spatial distribution was quite contagious rather than evenly distributed. Many small relatively isolated concentrations exist because of local topography and the availability of hard substrates, with often no possibility of adult abalone movement between them. Abalone are mobile, but adults likely only move over a range of a few hundreds of metres at most during their lives. Where abalone occur, abalone may further concentrate at times of spawning, which can make them particularly vulnerable to predation or harvest by humans. Predators only take what they can consume at that time, although they may stay in the area as long as food is available to them. In contrast, human fishers generally take all that are available to them at any time. Unfortunately, precise locations of historic abalone concentrations were never documented in a manner available to fisheries managers: in the early fishery, maintaining log books was not required, and when they were required, fishers either reported only by DFO Statistical Area or Subarea, i.e. a relatively large general area as their fishing location, or, as has been reported anecdotally, intentionally falsified their logs to ensure their particular fishing grounds remained known only to them. Precise geo-referenced locations of historical abalone concentrations are thus not generally available.

D. Fisheries Management: Concern was regularly expressed in scientific advice to resource managers about the apparent continuing decline in abundance of abalone. The early concern was not that abalone as a species would be extirpated in Canada, but rather that local, accessible populations might be decreased in abundance so much that risk of local extirpation might be high. Fisheries managers in reality can only attempt to manage the activities of humans, not the biological attributes of the resource being exploited per se, and natural factors affecting recruitment and abundance might dominate. The early conservation concern was reflected by continuous reduction in annual quotas in the early 1980's, but logistic difficulties in sampling this widely and contagiously distributed species made collection of comprehensive fisheries-independent abundance data difficult. Because fishers were targeting on abalone concentrations, catch-per-unit-effort (CPUE) declined little initially, as after fished concentrations were depleted of abalone, new concentrations were relatively easily found. CPUE was only noticeably affected when concentrations became so few and far between that search time for them became a major fishing factor. Biologists studying the species were also not sure if the observed low recruitment at that time (Tables 3,4) was perhaps part of a natural cycle in abundance, determined by natural causes, or indicative of over-exploitation. Time-series data were limited, making scientific data ambiguous, and with strong lobbying by industry for continuation of at least a reduced fishery, resource managers were hesitant to curtail fishing completely without strong scientific support. Instead, they gradually reduced annual quotas through to 1985 to the minimum level which fishers claimed would support.

Abalone fishing in Canada involved divers finding concentrations of abalone, and then harvesting all they could find above the minimum legal size limit. Over time, as previously cryptic animals become accessible, this had the potential to gradually deplete a population of most of its spawning adults, particularly if the minimum legal size limit was not most appropriate. Poaching, i.e. the illegal harvest of either legal or sublegal abalone, has made, or is making, abundance depletion more rapid.

Tegner (1993) questioned whether abalone in general were inherently unmanageable with traditional fishery approaches, given the group's biological characteristics and the effective searching ability and potential number of human fishers. Davis (1989) suggested that establishing harvest refugia for abalone might reverse the declining abundances of abalone species, but Tegner (1993) suggested that establishing a harvest refugia for a single taxon with the characteristics of abalone would likely be uneffective because of continued opportunity for poaching. She suggested refugia would be most effective if all harvest, at least by divers, was banned, but that as suggested by Sluczanowski (1984), rotating refugia may allow consideration of temporal and /or spatial variability in recruitment potential.

E. World-wide trends in Haliotis abundance: Abalone recruitment in general is not as high as expected from experience with observation of other commercially-exploited molluscs, notably bivalves. World-wide, many abalone species have declined significantly in abundance coincident with the establishment of intensive export fisheries. It is now recognised that as a group, abalone seem relatively vulnerable to over-exploitation (Tegner et al. 1996), and that particular attention must be given to monitoring and controlling their harvest (Tegner and Butler 1985; Prince et al. 1987, 1988; McShane et al. 1988; McShane 1992, 1995a,b). Reasons for this are not well understood for most abalone species, but Prince et al. (1988) suggested that for *Haliotis rubra* in Australia, this was because of limited larval dispersal. Widespread dispersal of meroplanktonic larvae should not be assumed for haliotids, and particularly if nothing is known about larval behaviour under field conditions. Prince et al. (1988) noted that abalone populations may be extremely affected by concentrated fishing within specific areas, and that this could lead to recruitment overfishing in local, harvested concentrations.

F. Changes in abalone abundance in British Columbia over time: Firstly, it should be noted that in the one known area today of historical abalone abundance in B.C. known not to have ever been subjected to industrial fishing, abalone abundance and average size remain relatively high (Table 1) and the population presumably healthy, i.e. with a high proportion of large abalone. This is a population of abalone in the immediate vicinity of William's Head Penitentiary near Victoria, B.C., where penitentiary guards have prevented nearshore access to both fishers and poachers in an effort to minimise opportunity for inmate escape (Wallace 1997, 1999). Although there is only one such site, this suggests that the coastal decline in abalone abundance may not have been the result of natural factors, such as disease. However, abalone diseases are known to exist, and an intensive abalone culture initiative in the 1980's was forced to cease operation because of extremely high mortality of abalone in the first few months after settlement due to a previously undescribed protozan parasite, *Labyrinthuloides haliotidis* (Bower 1986, 1987a, 1987b). Adult abalone were not noticeably affected by the parasite. It was not known how this facility became infected and studies to ascertain the prevalence of this parasite in the wild have not been conducted.

Fishery details may partially explain why the decrease in wild abalone abundance over the past few decades occurred. Firstly, the commercial fishery targeted larger animals (Sloan and Breen 1988), which may have impacted overall population fecundity greater than was realised in the early 1980's. There is no described stock-recruitment relationship for the species, but a precautionary approach (Richards and Maguire 1998) argues that management should maintain gamete production at a level which accommodates uncertainty. Only after the fishery closed was it recognised that the legal size limit of 100 mm shell length might be too low to maintain an appropriate reproduction level (Campbell et al. 1992).

Following from the abalone summary documents of Sloan and Breen (1988) and Jamieson (1989), resurveys of harvested areas have continued in northern British Columbia to the present (Table 2), with either the south-east Queen Charlotte Islands or the Central Coast sampled in any year. The surveys did not document absolute abalone abundance at any site, but only an index of abundance, specifically the number of abalone in 16 m^2 using a systematic survey design. In 1987, it looked like abalone recruitment in the Queen Charlotte Islands might possibly be increasing (Table 4), but no similar pattern was observed in the 1989 survey of the Central Coast (Table 3). Conservation of the species was considered a significant issue, and fishery closure was almost implemented that year. However, it was decided to conduct one more survey in the Queen Charlotte Islands to determine if the recruitment pulse observed in 1987 was being sustained. Results of this 1990 survey (Table 4) indicated it was not, and so the DFO took the then unprecedented step of closing all abalone fishing, initially for five years as proposed by Farlinger et al. (1991). This time period was chosen because abalone grow slowly and do not recruit to the fishery until they are 7-10 years, and so it would take a number of years for any substantial new abalone recruitment to become detectable. It should be noted that First Nations' food, social and ceremonial harvests have precedence in any fishing, and the fact that this fishery was closed as well indicates how serious the DFO felt the population decline was.

Subsequent surveys (Tables 3,4) have demonstrated no stock rebuilding, and so all fisheries remain closed indefinitely. In 1997, abundance in the Central Coast appears to have declined even further (Fig. 2), raising new concerns about both the effectiveness of the fishery closure with respect to stock rebuilding and the possibility that abalone levels may now be so low, at least at the survey sites, that reproduction can no longer effectively occur. It should be noted that with the survey protocol used, patch size or spatial distribution is not surveyed, only the abundance and size distribution of abalone at each predetermined survey site.

In recent years, there has been evaluation of the methodology used to survey abalone stocks in British Columbia (Campbell 1996) and consideration of criteria which might be used to reopen the northern abalone fishery in British Columbia if stocks rebuild (Campbell 1997). A common survey methodology has been used in all surveys to date to provide a data series of comparable data, but concern exists that this methodology is not sufficiently precise to detect small changes in population density (Farlinger and Campbell 1992). Campbell (1996) described advantages of modifying the present survey technique, but these have only been minimally implemented, in part because major methodology change would mean starting a new data series, with a short-term inability to then compare data. It was concluded that fishery reopening criteria could not be fully defined at this time due to a lack of data on the frequency and patch size of adult abalone concentrations which would be required to maintain sufficient recruitment for a healthy population. As mentioned above, studies on other abalone species indicated that larval dispersal is not as extensive as with other mollusc broadcast spawners. This makes the spatial distribution of abalone patches important. Also, dilution of gamete concentration through reduced adult spawner densities can reduce fertilisation success (Clavier 1992; McShane 1995a,b; Shepherd and Partington 1995), making both patch size and abalone density within a patch important variables.

Finally, for a species of limited adult mobility and limited larval dispersal, care has to be taken in weighing indices data only obtained from survey sites of known historical abalone abundance, but which have apparently been depleted of abalone by fishing. Abalone populations at such sites, if sufficiently depleted, may not be capable of rebuilding, so a time series of data may simply be documenting abalone extirpation at each specific site. To confirm that abalone depletion was more widespread, abalone abundance at random siting of representative locations in the general area were also surveyed, but these also showed no evidence of abalone population rebuilding as abalone densities at the random sites were not significantly different to those at the index sites (Campbell et al. 1998). These data confirm that the index sites are likely representative of abalone on the coast as a whole.

In 1997, PSARC (1997) made recommendations regarding development of a rebuilding strategy for abalone stocks, but to date, no active approach has been initiated. A conference is planned for late February, 1999, to evaluate rebuilding options.

G. Threats to abalone survival and reproduction:

a) *Poaching:* A major problem was, and probably still is, illegal harvesting (Farlinger and Thomas 1989; Farlinger 1990). Coincident with a reduction in the legal quota for abalone, recreational SCUBA diving and dive fisheries for other species were expanding, increasing the numbers of divers which were encountering abalone. Knowledge where abalone concentrations were became more widespread. Reduced quotas for abalone increased the price per kilogram in the late 1980's, and current abalone prices in British Columbia are estimated to range from \$55-110 kg^{-1} (B. Jubinville, DFO Fishery Officer, Nanaimo, BC, pers. comm., Jan 29, 1999), making it increasingly attractive by poachers to harvest abalone illegally. Undocumented, and potentially unreliable, sources suggested that the illegal fishery in 1990 at the time of the fishery closure may have been considerably larger than the then legal fishery (47.2 t), and that even now, the illegal fishery may be comparable to the 1989 quota fishery. DFO fishery officers try to enforce the law, but abalone volumes landed at any one time are often small and can be hidden, sometimes with other much larger volumes of legally-landed species. There have been a few significant arrests and convictions involving thousands of abalone. The problem may be a little like the illegal drug trade – for some people, value and potential gain appear sufficiently high to override the risk of being caught

b) The range and abundance of sea otters in British Columbia is expanding (average of 18.6% increase in number per year on the west coast of Vancouver Island; Watson 1997), following their reestablishment at a few isolated locations in the period 1969-72. The population has expanded from 89 animals introduced between 1969-72 to over 1522 in 1995 (Watson et al. 1997). Ultimately, unless extensively harvested in certain localities, sea otters can be expected to regain all of their original range, which includes most, if not all, habitats presently occupied by abalone. Abalone can coexist with sea otters, but at a relatively low density as cryptic individuals (Watson and Smith 1996). Abalone fisheries and unharvested sea otters are unlikely to coexist, as humans with SCUBA and sea otters are both very efficient predators and competitors for abalone.

Protection

Haliotis kamtschatkana is the only invertebrate species for which all fishing in British Columbia is totally banned. The Fisheries Act provides as much protection as can be done under existing legislation on the basis of specific recognition of the necessity for this species' conservation. However, because demand for abalone is high world-wide, in Canada at least, this has resulted in a dramatic increase in price per unit weight, with the result that illegal fishing, i.e. poaching, of abalone of all marketable sizes continues to be a serious problem. Whether a COSEWIC designation will assist in preventing further poaching and/or in abalone stock rebuilding initiatives is not known at this time. It may mostly depend on how the judicial system ultimately penalises convicted offenders.

Recommendations/Management Options

The DFO recognises that abalone conservation continues to be a serious issue and that legal fishery closure has to date not resulted in a rebuilding of abalone stocks. Why this has not occurred is not precisely known, but as a result, the DFO has recommended a proactive approach to stock rebuilding. Continued stock decline may be both because abalone densities in many abalone concentrations are now too low to sustain these populations and/or because of the unknown magnitude of continued illegal harvest, i.e. the continued depletion of the few abalone concentrations which remain. As concentrations of abalone become fewer and smaller, it presumably takes less poaching to continue to decrease overall abalone abundance even further. It has been documented by managers that available regulation enforcement resources just do not seem adequate to prevent all regulation infringements. Mobilising broader public support and recognition of the need for abalone conservation may help in abalone population rebuilding.

It is not clear at this time whether abalone populations are approaching a new state of equilibrium, i.e. where reproduction equals removal from the population (by death, natural predation or harvest), or whether populations of abalone are slowly being extirpated. The continued decline in abundance at the index sites suggests the latter may be occurring and that an equilibrium has not yet been established. It is not known where equilibrium levels might be. This is suggested, in the Central Coast at least, by an increasing number of index sites with zero abalone (Table 5). However, while data interpretation is difficult and potentially contentious, there is general agreement, as documented by recent Pacific Scientific Advice Review Committee (PSARC) reports (e.g. Campbell et al. 1998) that abalone densities are much lower now than two decades ago, variability among sites and unknown fishing histories at each site makes accurate identification of causal factors impossible, and that densities are now so low that statistical analysis of relative measured change in abundance may no longer be meaningful.

The threat of regional abalone extirpation might be reduced if patches of relatively high abalone density, such as might occur in marine protected areas where effective protection from human-caused mortality could be assured, could be established and maintained. Because of its reproductive biology, abalone may have unknown threshold population densities where abundance in a patch may relatively quickly drop to extinction if density drops below a critical level.

Other species of abalone have been cultured, and a number of groups, particularly First Nations, have proposed the establishment of abalone hatcheries to enhance local abalone populations and possibly re-establish commercial abalone fishing. However, at this time, the feasibility of abalone culture in British Columbia is unproven.

From a sustainable abalone population perspective, determining an appropriate historical population size baseline for abalone may be a major issue for COSEWIC. Humans have likely impacted abalone abundance twice – initially by eliminating a major natural predator, which is assumed to have increased abalone abundance, and then by overharvesting abalone, which decreased adult abundance, perhaps returning it to more historic levels. Over the extreme long term, i.e. centuries, abalone abundance over much of its range may have been relatively low, at least compared to the 1950s and 1960s, if predation of abalone by sea otters was high. From a COSEWIC status perspective, this seems the opposite of most other species impacted by humans. However, we have no scientific data on abundance of abalone in the long ago past. All we know today is that while natural predation on abalone may have been high, recent removal by fishers was also high, and with both sources of mortality together, abalone are unlikely to occur in abundance anywhere on the coast. The ranges of sea otters and abalone may never have totally overlapped on a microhabitat scale (for example, native people hunted sea otters as well as abalone, and sea otters thus tended to avoid the immediate areas around native villages, which were relatively abundant), but the ranges of today's fishers and abalone almost certainly do. Sea otters also prey on many species, and may not target on abalone in the same directed manner that at least some fishers do today.

Summary

There is little information on circumstances other than habitat loss, which is not the case here, which might surround biological extirpation or extinction of a marine species. Jamieson (1993) described conditions which make a species particularly vulnerable to extirpation from overfishing: relatively large size, occurrence in a relatively restricted geographical range near human settlement, exceptional market demand to justify exploitation at very low stock densities, and associated with their relatively large size, a relatively long lifespan and thus likely, a normally low annual recruitment. Abalone world-wide possess all these characteristics, and in California, Davis et al. (1996) and Tegner et al. (1996) report the near extinction of the white abalone, *H. sorenseni*. With this uncertainty around the status of northern abalone, application of a precautionary approach is warranted.

Recent decadal changes in abundance should perhaps primarily be considered in assigning abalone stock status, as who knows what the past really was and what the future will bring. Sea otters, for a variety of reasons, may never, or at least not in the foreseeable future, re-establish their complete historical range. I suggest abalone abundance should be considered mostly on the basis of what potential abalone abundance could be now. COSEWIC considers relative threats to a species and the likelihood of continued species abundance decline. Abalone may be a species which is adapted to live successfully in isolated patches of abundance, but with its reproductive biology, it does not seem to be a species adapted to live successfully at a low density of abundance, i.e. with individuals distant from each other. Humans, with their relatively insatiable demand for this resource, may be particularly effective in establishing a spatial pattern of abundance different from that which would be established through natural predation.

Data, limited though it may be, have continued to document that abundance is low and apparently still declining (Tables 3,4; Fig. 2), even following fishery closure. As sea otters slowly expand their range, additional mortality through predation can be expected. Efforts need to be initiated as soon as possible to establish patches, even if relatively isolated from each other, of substantial abalone density per unit area to ensure the continued reproductive success of abalone in Canada. In addition, development of a coast-wide stock rebuilding strategy would seem advantageous.

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References

Adkins, B.E. Abalone surveys in South Coast areas during 1982, 1985 and 1886. Can. Tech.. Rep. Fish. Aquat. Sci. 2089:72-96.

Boutillier, J.A., W. Carolsfeld, P.A. Breen, and K. Bates. 1984. Abalone survey in the Estevan Group and Aristazabal Island, May 1983. Can. Ms.. Rep. Fish. Aquat. Sci. 1747: 60 p.

Boutillier, J.A., W. Carolsfeld, P.A. Breen, S. Farlinger, and K. Bates. 1985. Abalone resurvey in the southeast Queen Charlotte Islands, July 1984. Can. Ms.. Rep. Fish. Aquat. Sci. 1818: 87 p.

Bower, S.M. 1986. The life cycle and ultrastructure of a new species of thraustochytrid (Protoza: Labyrinthormorpha) pathogenic to small abalone. Abstract in: 2nd Int. Colloq. Pathol. Mar. Aquat., Portugal.

Bower, S.M. 1987a. *Labyrinthuloides haliotidis* n. sp. (Protoza: Labyrinthormorpha), a pathogenic parasite of small juvenile abalone in a British Columbia mariculture facility. Can. J. Zool. 65:1996-2007.

Bower, S.M. 1987b. Pathogenicity and host specificity of *Labyrinthuloides haliotidis* (Protoza: Labyrinthormorpha), a parasite of juvenile abalone. Can. J. Zool. 65: 2008-2012.
.

Breen, P.A. 1980a. Muscled mollusc: the northern abalone. Diver 6(6): 26-28.

Breen, P.A. 1980b. Measuring fishing intensity and annual production in the abalone fishery of British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 947: 49 p.

Breen, P.A. 1986. Management of the British Columbia fishery for northern abalone (*Haliotis kamtschatkana*). P.300-312. *In* North Pacific Workshop on Invertebrate Stock Assessment and Management of Invertebrates. *Edited by* G.S. Jamieson and N. Bourne. Can. Spec. Publ. Fish. Aquat. Sci. 92.

Breen. P.A. and B.E. Adkins. 1979. A survey of abalone populations on the east coast of the Queen Charlotte Islands, August 1978. Fish. Mar. Serv. MS rep. 1490: 125 p.

Breen. P.A. and B.E. Adkins. 1981. Abalone surveys and tagging conducted during 1979. Can. Ms.. Rep. Fish. Aquat. Sci. 1623: 88 p.

Calderwood, G. 1985. Technological advances in the field of abalone mariculture. Final Rep. (1982-1985) Pacific Trident Mariculture Ltd., Victoria, B.C., 125 p. Contract to Dep. Of Supply and Services, canada, No. 053B. FP 501-2-005.

Campbell, A. 1996. An evaluation of abalone surveys off southeast Queen Charlotte Islands. Can. Tech. Rep. Fish. Aquat. Sci. 2089:111-131.

Campbell, A. 1997. Possible criteria for reopening the Northern Abalone (*Haliotis kamtschatkana*) fishery in British Columbia. Can. Stock Assess. Sec. Res. Doc. 97/64: 47 pp.

Campbell, A., I. Manley and W. Carolsfeld. 1992. Size at maturity and fecundity of the abalone, *Haliotis kamtschatkana*, in northern British Columbia. Can . Ms. Rep. Fish. Aquat. Sci. 2169:47-65.

Campbell. A., I. Winther, B. Adkins, D. Brouwer and D. Miller. 1998. Survey of the Northern Abalone (*Haliotis kamtschatkana*) in the Central Coast of British Columbia, May 1997. Can. Stock Assess. Sec. Res. Doc. 98/99: 28 p.

Carolsfeld, W., S. Farlinger, B.C. Kingzett, N.A. Sloan and G. Thomas. 1988. Abalone resurvey in the southeast Queen Charlotte Islands, June 1987. Can . Ms. Rep. Fish. Aquat. Sci. 1966: 90 p.

Clavier, J. 1992. The ormer (*Haliotis tuberculata*) fishery of France and the Channel Islands. p. 454 - 457. *In* S. A Shepherd, M. J. Tegner and S. A Guzman del Proo (eds.) Abalone of the world: biology, fisheries and culture. Fishing News Books, Blackwell Sci. Pub. Ltd., Oxford, U. K., 608 p.

Cox, K.W. 1962. California abalone, Family Haliotidae. Calif. Fish and Game, Fish. Bull. 118:

Cripps, K. and A. Campbell. 1998. Survey of abalone populations at Dallain Point and Higgins Pass, Central Coast of British Columbia, 1995-96. Can. Ms. Rep. Fish. Aquat. Sci. 2445:31 p.

Davis, G.E. 1989. Designated harvest refugia: the next stage of marine fishery management in California. Calif. Coop. Oceanic Fish. Invest. Rep. 30: 53-58.

Davis, G.D., P.L. Haaker, and D.V. Richards. 1996. Status and trends of white abalone at the California Channel Islands. Trans. Am. Fish. Soc. 125: 42-48.

Emmett, B and G.S. Jamieson. 1988. An experimental transplant of of northern abalone, *Haliotis kamtschatkana,* in Barkley Sound, British Columbia. Fish. Bull., U.S. 87: 95-104.

Estes, J.A. and G.R. VanBlaricom. 1985. Sea otters and shellfisheries, p. 187-235. *In* Marine Mammals and Fisheries. *Edited by* J.R. Beddington, R.J.H. Beverton. And D.M. Lavigne. George Allen and Unwin, London.

Farlinger, S. 1990. Review of the biological basis for management of the British Columbia abalone fishery. Can. Ms. Rep. Fish. Aquat. Sci. 2099:41-51.

Farlinger, S., G. Thomas, D. Anderson, D. Chalmers and A. Tyler [editors]. 1991. Pacific Stock Assessment Review Committee (PSARC) Annual Report for 1990. Can. MS Rep. Fish. Aquat. Sci. 2095: 201 p.

Farlinger, S. and K. Bates. 1986. Abalone survey in the Estevan Group and Aristazabal Island, June, 1985. Can. Ms. Rep. Fish. Aquat. Sci. 1986: 45p.

Farlinger, S. and A. Campbell. 1992. Fisheries management and biology of northern abalone, *Haliotis kamtschatkana*, in the northeast Pacific. p. 395-406. *In* Abalone of the world: Biology, Fisheries and Culture. Fishing News Books. *Edited by* Shepherd, S.A. , M.J. Tegner and S.A. Guzman del Proo.608 p.

Farlinger, S. and G. Thomas. 1989. Review of the abalone fishery in British Columbia. PSARC Doc. I88-10. Summarised in Can. Ms. Rep. Fish. Aquat. Sci. 2020: p. 138.

Farlinger, S., G. Thomas and W. Carolsfeld. 1991. Abalone resurvey in the Estevan Group and Aristalzabal Island, June 1989. Can. Ms. Rep. Fish. Aquat. Sci. 2104: 39 p.

Fedorenko, A.Y. and P.E. Sprout. 1982. Abalone biology, fishery regulations, commercial catch (1952-1980), and current state of resources in British Columbia. Can. Man. Rep. Fish. Aquat. Sci. 1658: 74 pp.

Fournier, D.A. and P.A. Breen. 1983. Estimation of abalone mortality rates with growth analysis. Trans. Am. Fish. Soc. 112: 403-411.

Hines, A.H. and J.S. Pearse. 1982. Abalone, shells and sea otters: dynamics of prey populations in central California. Ecology 63: 1547-1560.

Jamieson, G.S. 1989. Status of the Northern Abalone, *Haliotis kamtschatkana*, in Canada. Can. Field-Naturalist 103(2):153-158.

Jamieson, G.S. 1993. Marine invertebrate conservation: evaluation of fisheries overexploitation concerns. Am. Zool. 33: 551-567.

Johnson, A.M. 1982. Status of Alaska sea otter populations and developing conflicts with fisheries. p. 293-299. Trans. N. Am. Wildl. Nat. Res. Conf., Washington, D.C.: Wildlife Management Institute

Levitan, D.R. and M.A. Sewell. 1998. Fertilization success in free-spawning marine invertebrates: review of the evidence and fisheries implications. *In* Proceedings of the North Pacific Symposium on Invertebrate Stock Assessment and Management. *Edited by* G.S. Jamieson and A. Campbell, Can. Spec. Publ. Fish. Aquat. Sci. 125: 159-164.

McLean, J.H. 1966. West American prosobranch gastropoda: Superfamilies Patellacae, Pleurotomariacea, and Fissurellacea. Ph.D. dissertation. Stanford University, CA. 255 p.

McShane, P. E. 1992. Early life history of abalone: a review. p. 120 - 138 *In* S. A Shepherd, M. J. Tegner and S. A Guzman del Proo (eds.) Abalone of the world: biology, fisheries and culture. Fishing News Books, Blackwell Sci. Pub. Ltd., Oxford, U. K., 608 p.

McShane, P. E. 1995a. Recruitment variation in abalone: its importance to fisheries management. Mar. Freshwater Res. 46: 555 - 570.

McShane, P. E. 1995b. Estimating the abundance of abalone: the importance of patch size. Mar. Freshwater Res. 46: 657 - 662.

McShane, P. E., K. P. Black and M. G. Smith. 1988. Recruitment processes in *Haliotis rubra* (Mollusca: Gastropoda) and regional hydrodynamics in southeast Australia imply localised dispersal of larvae. J. Exp. Mar. Biol. Ecol. 124: 175 - 203.

Mottet, M.G. 1978. A review of the fishery biology of abalones. Wash. State Dept. Fish. Tech. Rep. 37: 81 pp.

Olson, S. 1984. Shellfish Enhancement report. NOAA, NMFS, Final Rep. For Project 1-144-R. Washington State Dep. Fisheries. 85 p. (Mimeo)

Paul, A.J. and J.M. Paul. 1981. Temperature and growth of maturing *Haliotis kamtschatkana* Jonas. Veliger 23: 321-324.

Prince, J. D., T. L. Sellers, W. B Ford and S. R. Talbot. 1987. Experimental evidence for limited dispersal of haliotid larvae (genus *Haliotis*; Molluscs: Gastropoda). J. Exp. Mar. Biol. Ecol. 106: 243 - 263.

Prince, J. D., T. L. Sellers, W. B Ford and S. R. Talbot. 1988. Confirmation of a relationship between the localized abundance of breeding stock and recruitment for *Haliotis rubra* Leach (Molluscs: Gastropoda). J. Exp. Mar. Biol. Ecol. 122: 91-104.

Quayle, D.B. 1971. Growth, morphometry and breeding in the British Columbia abalone (*Haliotis kamtschatkana* Jonas). Fish. Res. Board Can. Tech. Rep. 279: 84 p.

Richards, L.J. and J.-J. Maguire. Recent international agreements and the precautionary approach: new directions for fisheries management science. Can. J. Fish. Aquat. Sci. 55:1545-1552.

Shepherd, S. A. and D. Partington. 1995. Studies on southern Australian abalone (Genus *Haliotis*). XVI. Recruitment, habitat and stock relations. Mar Freshwater Res. 46: 669 - 680.

Sloan, N.A. and P.A. Breen. 1988. Northern abalone, *Haliotis kamtschatkana*, in British Columbia: fisheries and synopsis of life history information. Can. Spec. Publ. Fish. Aquat. Sci. 103: 46 p.

Sluczanowski, R.P. 1984. A management oriented model of an abalone fishery whose substocks are subject to pulse fishing. Can. J. Fish. Aquat. Sci. 41: 1008-1014.

Tegner, M.J. 1993. Southern California abalones: can stocks be rebuilt using marine harvest refugia. Ca. J. Fish. Aquat. Sci. 50: 2010-2018.

Tegner, M.J., L.V. Basch and P.K. Dayton. 1996. Near extinction of an exploited marine invertebrate. TREE 11: 278-280.

Tegner, M. J., and R. A. Butler. 1985. Drift-tube study of the dispersal potential of green abalone (*Haliotis fulgens*) larvae in the southern California Bight: implications for the recovery of depleted populations. Mar. Ecol. Prog. Ser. 26: 73 - 84.

Thomas, G., S. Farlinger and W. Carolsfeld. 1992. Abalone resurvey in the southeast Queen Charlotte Islands in 1990. Can. Ms. Rep. Fish. Aquat. Sci. 2166: 93 p.

Thomas, G. and A. Campbell. 1996. Abalone resurvey in Aristazabal island, the Estevan Group and Banks Island, June 1993. Can. Tech. Rep. Fish. Aquat. Sci. 2089:97-109.

Wallace, S. 1997. The role of marine reserves in the management of n0n-migratory species in coastal British Columbia. *In* The Design and Monitoring of Marine Reserves. Univ. of British Columbia, Vancouver, Fisheries Centre Res. Rep. 5: 24-25

Wallace, S.S. 1999. Evaluating three forms of marine reserves on northern abalone (*Haliotis kamtschatkana*) populations in British Columbia, Canada. Cons. Biol.: In press.

Watson, J.C. 1993. The effects of sea otter (*Enhydra lutris*) foraging on shallow rocky communities off northwestern Vancouver Island, British Columbia. Ph.D. dissertation, Univ. California, Santa Cruz, 169 p.

Watson, J.C., G.M. Ellis, T.G. Smith and J.K.B. Ford. ? Updated status of the sea otter, *Enhydra lutris*, in Canada. Canadian Field Naturalist 111(2): 277-286

Watson, J. C. and T. G. Smith. 1996. The effects of sea otters on invertebrate fisheries in British Columbia: a review. Can. Tech. Rep. Fish. Aquat. Sci. 2089: 262 - 303.

Winther, I., A. Campbell. G.A. Thomas, B.E. Adkins and B.G. Clapp. 1995. Abalone resurvey in the southeast Queen Charlotte Islands, 1994. Can. Ms. Rep. Fish. Aquat. Sci. 2273: 46 p.

Table 1: Comparison of abalone relative abundance and mean size (size range in brackets) at three sites in British Columbia. Prison reserve = abalone fishery closure enforced by prison guards; Ecological reserve = abalone fishery closure enforced by fishery officers, whenever possible, and by a full-time lighthouse keeper; Coast-wide sites = abalone fishery closure only enforced by fishery officers, whenever possible. (modified from Wallace 1999, Table 1). CPUE = abalone catch per minute of diving.

Location	Number of abalone (n)	CPUE (n/min)	Average Size (mm)	% >130 mm in Size
Prison Reserve	211	0.77	115.6 (62-154)	26.5
Ecological Reserve	241	0.70	99.7 (40-148)	8.8
Coast-wide Sites	9	0.05	109.4 (72-127)	0

Table 2: Surveys of abalone abundance by region in northern British Columbia.

Year	Central Coast	Queen Charlotte Islands	Reference
1978		x	Breen and Adkins 1979
1979	x		Breen and Adkins 1981
1983	x		Boutillier et al. 1984
1984		x	Boutillier et al. 1985
1985	x		Farlinger and Bates 1986
1987		x	Carolsfeld et al. 1988
1989	x		Farlinger et al. 1991
1990		x	Thomas et al. 1992
1993	x		Thomas and Campbell 1996
1994		x	Winther et al. 1995
1995-96	x		Cripps and Campbell 1998
1997	x		Campbell et al. 1998

Table 3: Abalone densities (number m^{-2}) from 25 comparable sites in the Central Coast resurveyed in 1983, 1985, 1989 and 1993 (from Thomas and Campbell 1996) and in 1997 (Campbell et al. 1998). [1] = 92-99 mm size range; [2] = 100-106 mm size range; [3] = only exposed abalone, but a decline in abundance is still evident (e.g. in 1993, total density of exposed abalone was 0.48).

Cohort	Year				
	1983	1985	1989	1993	1997[3]
Total abalone	1.43	1.57	0.56	0.53	0.27
Legal size (100^+ mm)	0.22	0.34	0.11	0.09	0.06
Prerecruits (94-101 mm)	0.18	0.25	0.08	0.06	0.04[1]
Recruits (102-107 mm)	0.10	0.14	0.03	0.03	0.02[2]

Table 4: Abalone densities (number m^{-2}) from 28 comparable sites in the Queen Charlotte Islands resurveyed in 1984, 1987, 1990 and 1994 (from Winther et al. 1995).

Cohort	Year				
	1979	1984	1987	1990	1994
Total abalone	3.54	0.69	0.79	0.44	0.30
Legal size (100^+ mm)	0.30	0.09	0.13	0.07	0.06
Prerecruits (92-99 mm)	0.27	0.08	0.07	0.04	0.03
Recruits (100-106 mm)	0.14	0.04	0.05	0.04	0.02

Table 5: Summary, by year, of the number of sites where no legal abalone nor abalone of any size were found in comparable sites on the Central Coast of British Columbia during 1978-80 to 1997. Values in brackets are percentages of 24 sites. (from Campbell et al. 1998, Table 4). Note: Only 11 common sites go back to 1978-80, and these 11 sites are included in the 24 sites which are common from 1989 onwards.

	1979-80	1989	1993	1997
		Legal Abalone		
11 common sites	0	1	2	6
24 common sites	n/a	8 (33.3)	8 (33.3)	15 (62.5)
		Total Abalone		
11 common sites	0	0	0	3
24 common sites	n/a	1 (4.2)	1 (4.2)	5 (20.8)

Figure 1: Reported northern abalone landings and quotas between 1972-98 in British Columbia.

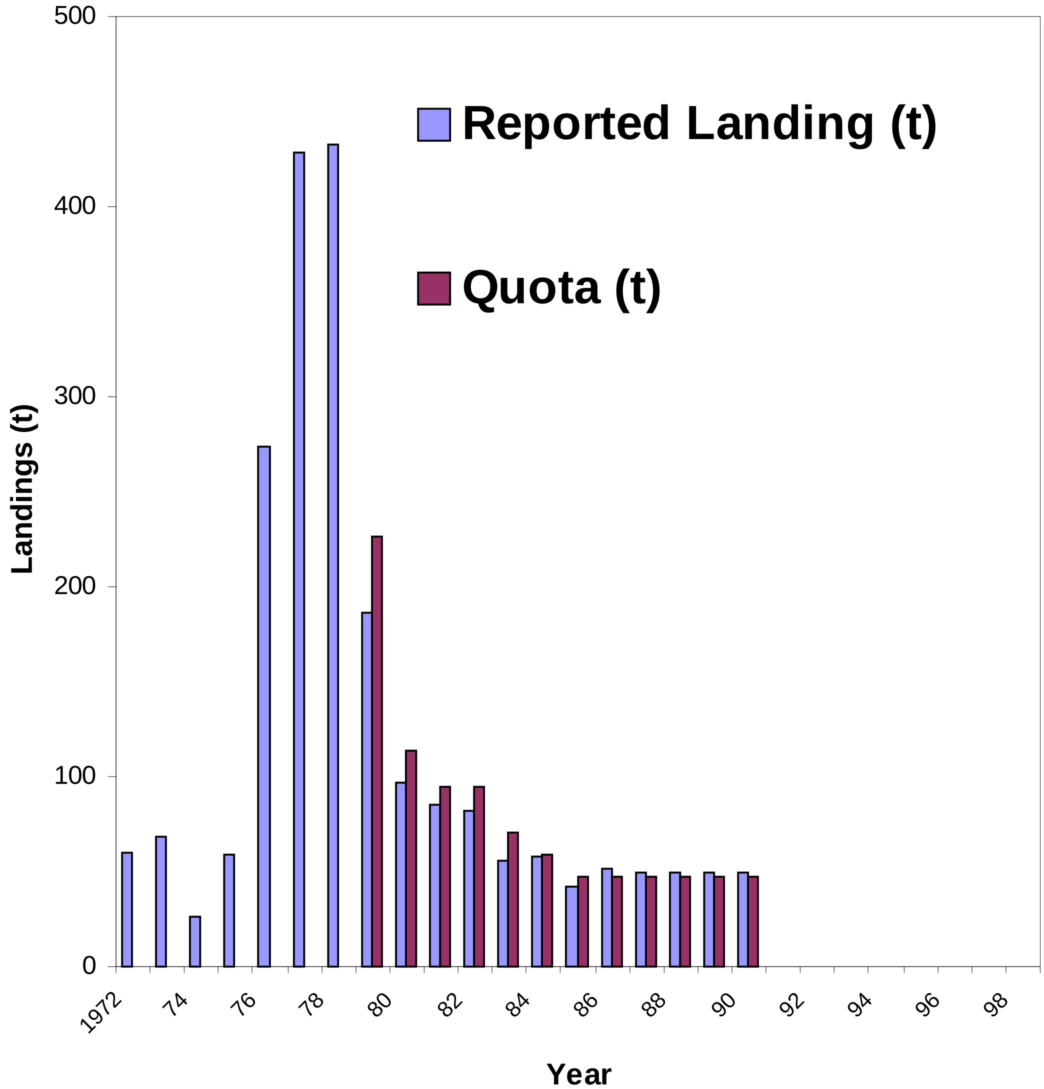

Figure 2: Mean density of total northern abalone per m^2 from surveys in the Queen Charlotte Islands and Central Coast (see Tables 3 and 4).