ISSN 0738-9388

Volume: 48 THE FESTIVUS ISSUE 3

The "Cambrian Explosion" – a study of the abnormally large population of *Haliotis kamtschatkana kamtschatkana* / *kamtschatkana assimilis* "intergrades" following species decline due to several years of unusually warm temperatures in San Luis Obispo County, California

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INTRODUCTION

This article describes an intriguing event that took place in the Morro Bay area of Central California from the late 1950's to about 1968. It began with a serious ecological change which caused an apparent disruption of the usual ocean currents and temperature which lasted approximately two years: 1957 and 1958 (Cox, 1962). During this period, the sea temperature was unusually warm, and the usual heavy growth of brown algae (kelp) that generally grows abundantly in the cold (10-12 degrees Celcius) spring and summer seas, didn't appear. The local *Haliotis rufescens* Swainson, 1822, populations became severely food depleted and ceased growing normally. Thus, commercial abalone divers were unable to harvest sufficient numbers of legal-sized abalone to sustain the fishery. Many divers living in the Morro Bay area left the fishery and took up other lines of work. The abnormally warm water conditions persisted for over two years, and many adult abalone lost tissue size dramatically, stopped producing gonadal tissue (gametogenesis), and didn't spawn. The usual abundance of red and brown algal *Haliotis* food species ceased to exist, and the underwater Morro Bay area assumed the appearance of a barren wasteland (D. Gallagher, S. Pearce, G. Bickford, K.W. Cox, personal communication).

This article also confirms a suspicion long held by a number of specialists in West Coast *Haliotis* taxonomy: that the populations of abalone which have been called *H. kamtschatkana kamtschatkana* and *H. kamtschatana assimilis* which range from throughout California and into Mexico actually represent a single species, and not a pair of subspecies. A more thorough and detailed study supporting this conclusion is in progress.

OBSERVATIONS AND DISCUSSION

In 1959, the cold-water temperatures abruptly returned, and extremely rapid growth of large, brown algal forms resumed, especially *Nereocystis leutkeana*, the large "Bull" kelp which is the primary food for the *Haliotis* species of this area (with the possible exception of *H. cracherodii cracherodii* Leach, 1814). The animals which survived the two-year warm water period, began growing rapidly – both shell and animal - developing gonadal tissue and spawning profusely within a few months (in late 1959, and again in mid 1960). Many of the divers who had left the fishery, returned in 1961 to discover that very large numbers of sub-legal-sized animals had rapidly grown and become legal size. Huge landings of red abalones were suddenly common-place in the Morro Bay fishery. At depths greater than 15 m (50 feet), occasional specimens of *H. kamtschatkana* ssp. could be observed by divers who were harvesting the much larger red abalone (*H. rufescens*). They were of little or no interest to the great majority of commercial *Haliotis* divers, as they were too small (usually <125 mm), not very common, and no fishery

existed for the species. However, not being regulated by a size limit in the early 1960's, specimens of *H. kamtschatkana* ssp. could be taken legally.

It was about this time (1960-1961) that I first started diving the Morro Bay area commercially, and I almost immediately noticed these small *Haliotis* and started paying close attention to them, as they were considered an uncommon species to shell collectors. At that time, most I observed were "older" specimens, and it was unusual to find shells that weren't damaged by erosion and/or boring or encrusting organisms on their exterior surfaces. Young fast-growing specimens appeared nonexistent. What I hadn't realized at the time was that the warm water temperature and lack of algal food species that had existed in the late 1950's, had affected more than just the large red abalone - additionally it had had a profound effect on this species (and very probably other algae grazing mollusks) as well. Thus it was in about the fall of 1962 when I first started noticing the incredible phenomenon that was beginning to occur throughout many areas outside of approximately 15 m depth: small sub-adult (50-75 mm) *H. kamtschatkana* ssp. were starting to move out of the protection of crevices, where they were too small and hidden to be noticed previously. Careful examination of these animals, reinforced with knowledge gained a few years later in a commercial *Haliotis* hatchery, clearly indicated they were two to three years old (50-75 mm). Closer to shore, in shallower water (approximately 8-12 m), many juvenile specimens of *H. rufescens* became apparent, protected in crevices, with occasional 75 to 80 mm specimens starting to move out onto more exposed surfaces as well. This was happening in areas where virtually all older legal sized animals had been previously harvested. It was becoming very apparent that both species of *Haliotis* were undergoing "population explosions" as juveniles and sub-adults of both species (approximately 2-3 years of age) were abundant. Further, it was clear that these small animals were the result of spawnings that had occurred and coincided with the radical transformation that had taken place with the return of cold water and copious algal growth in 1959. From 1962 to 1965, the numbers of these fast-growing, small, adult *H. kamtschatkana* ssp. increased, and by 1964-1965, many were measuring 100 to 125+ mm. All were clearly the fast-growing, thin-shelled "new growth" animals from the extraordinarily successful recruitment events that had resulted from the spawnings of 1959 and 1960. The few older animals that were mixed in with this population were very obvious, being thick-shelled, mature, badly eroded and/or encrusted, and often almost senile. It was evident from the extremely bright and varied coloration of the thin and fast-growing shells of this population, that their diet was rich in species of red algae, in addition to the brown alga *Nereocystis leutkeana*, as the "genetic" chevron-like color patterns were heavily blended with intense shades of red. This contrasts with the dull pale blue-green colors which are so often observed in specimens from Southern California and Baja California, Mexico – the result of a diet of almost entirely brown algae.

Remarks: At the time of this writing (June, 2016), a similar situation is occurring on the coast of California that may be a parallel to the disastrous environmental conditions of 1957-1958. For the past year, a warm water mass of unknown origin has existed off the coast that has prevented the normal regrowth of the large brown algal species that sustain the *Haliotis* species, sea urchins, and other herbivorous mollusks. As a result, starvation on a mass scale is happening with the *Haliotis* animals ceasing to add new shell increment, visibly losing weight and weakening where many

cannot maintain attachment to the bottom substrate and are torn loose during large winter swells. Cursory diving these areas reveals that all algae food species are gone and that the abalone are in a tissue wasting state. Additionally, a massive increase of biomass of the purple sea urchin, *Strongylocentrotus purpuratus* has coincided with this warm water increase and large areas have become completely denuded of what sparse algae remains due to this sea urchin's aggressive feeding. How long these warm water conditions will remain is unknown. A second warming trend has additionally been induced by a large "El Niño" event which is occurring simultaneously and may exacerbate this warm water problem. How long these El Niño conditions will remain in effect is also currently unknown.

CONCLUSIONS

Plates 1 through 3 illustrate examples of these brightly colored *H. kamtschatkana* ssp. specimens from the "Cambrian Explosion" – so named as the small town of Cambria, near the Hearst Castle at San Simeon, is near the center of the area where this brief and extreme population explosion was observed. During the years 1963-1965, literally thousands of *H. kamtschatkana* ssp. could be observed during 4-5 hours of diving commercially for the larger red abalone. Unfortunately, in 1968, the Sea Otter, *Enhydra lutris*, encroached into this area of the California coastline, and decimated both the red abalone fishery and all exposed animals (over approximately 35-40 mm) of this beautiful small abalone species. To my knowledge, extremely few *H. kamtschatkana* ssp. specimens had been taken from this area, as virtually no commercial abalone divers of that time collected these small *Haliotis.* Thus, the specimens illustrated on these plates may represent a large percentage of the "Cambrian Explosion" *H. kamtschatkana* ssp. specimens that exist in collections.

The Cambria area is located approximately in the center between the areas where what has been called the southern subspecies (*H. kamtschatkana assimilis* Dall, 1878) and northern subspecies (*H. k. kamtschatkana* Jonas, 1845) are distributed. Interestingly, the morphology of the *H. kamtschatkana* ssp. specimens collected in the Cambria area exhibit traits of both subspecies, which explains why this localized population could be described as "intermediate" between the typical northern and southern forms. These differences may be described as follows: (1) Shell proportions - Northern shells are more elongate with an elevated spire; southern specimens are more round in proportion and the spire is usually low and often depressed into shell; (2) Surface sculpture - Northern shells have a quite lumpy surface, often with strong folded ridges, and usually show little, or very weak, spiral ribbing; southern specimens often have a smooth surface usually lacking a lumpy surface, and frequently have strong spiral ribbing. (3) Groove below row of holes - Northern shells possess a strong and deep channel in the peripheral area between the holes and columella; southern shells have a much weaker and more shallow channel in this area. (4) Shell thickness - Northern shells tend to be quite thin and very light in weight; southern shells are often thicker and heavier. On Plate 1, Images 1-8 illustrate shells of a more northern morphology, whereas Images 9-16 illustrate shells of a more southern morphology. The remainder of the specimens on all three plates show a mixture of characteristics from the typical northern and southern forms and could be best be described as "intermediate" between the two extremes. Additional specimens of both subspecies in their more typical forms are illustrated on Plates 32 and 33

in *Abalone Worldwide Haliotidae* (Geiger & Owen, 2012).

There is debate whether the species *kamtschatkana* is properly parsed into two subspecies (*kamtschatkana kamtschatkana* and *kamtschatkana assimilis*), is just one single highly variable species, or should become two different species. If two subspecies or even two different species designation is indeed appropriate, there is debate on the range and characteristics of the two. Owen and Raffety plan to consider these subjects, review countless shell specimens of these enigmatic animals, and draw a conclusion of how these issues should be resolved. This will take place in a future publication, so for the time being, the current designation of subspecies is being withheld for the article at hand.

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In Memoriam

Robert Kershaw of Narooma, Australia, passed away on July 1, 2016, after a battle with an aggressive form of skin cancer. He will be sorely missed by friends, family and the malacological community. Robert discovered a new subspecies of abalone on Niue Island, which was named after him by his lifelong friend Buzz Owen as *Haliotis jacnensis kershawi* Owen, 2012. A more lengthy and proper memoriam is being written by Buzz Owen and will be published in a future issue of The Festivus.

Miriam & Buzz Owen, and Robert Kershaw at Lord Howe Is.

Haliotis jacnensis kershawi Owen, 2012, 13.0 mm
Robert Kershaw Collection

ISSN 0738-9388

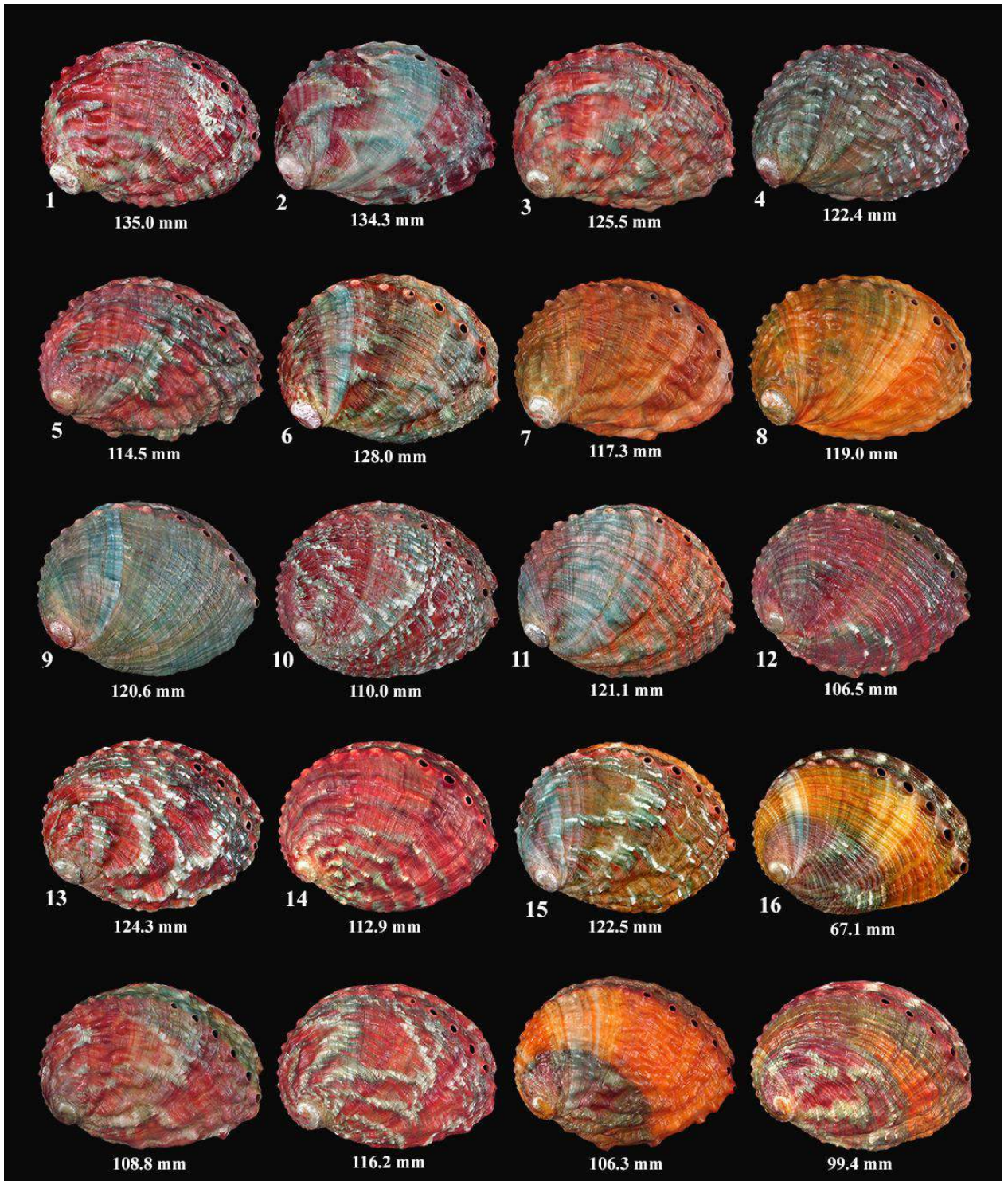

Plate 1

All Rows: *Haliotis kamtschatkana kamtschatkana/kamtschatkana assimilis*. 1-8 = more "northern" morphology. 9-16 = more "southern" morphology. Bottom row variable (more or less intermcdiate morphology). Cambria to Point Estero, California. 20-25 m. Live taken 1961-1963.

ISSN 0738-9388

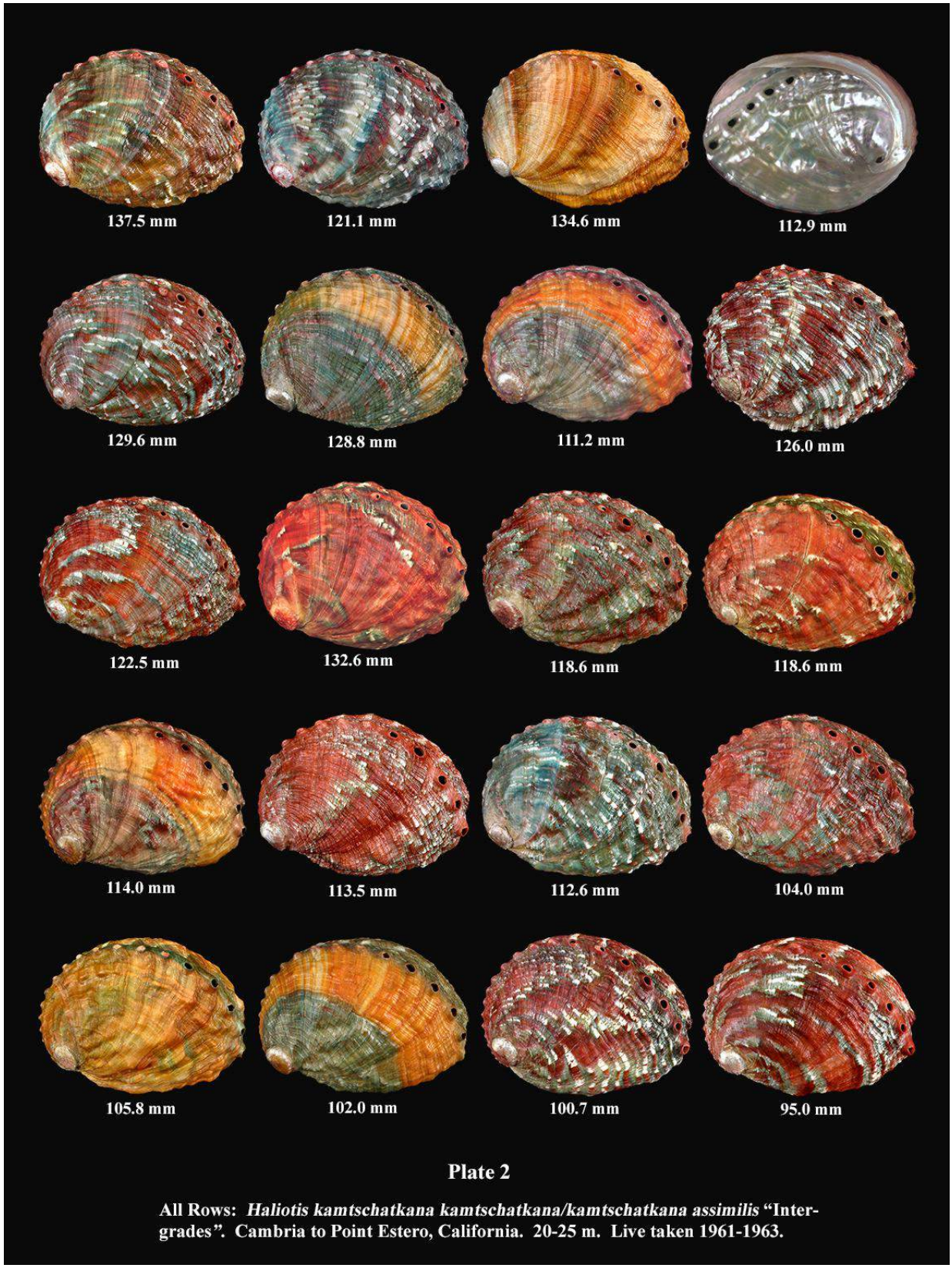

Plate 2

All Rows: *Haliotis kamtschatkana kamtschatkana/kamtschatkana assimilis* "Intergrades". Cambria to Point Estero, California. 20-25 m. Live taken 1961-1963.

ISSN 0738-9388

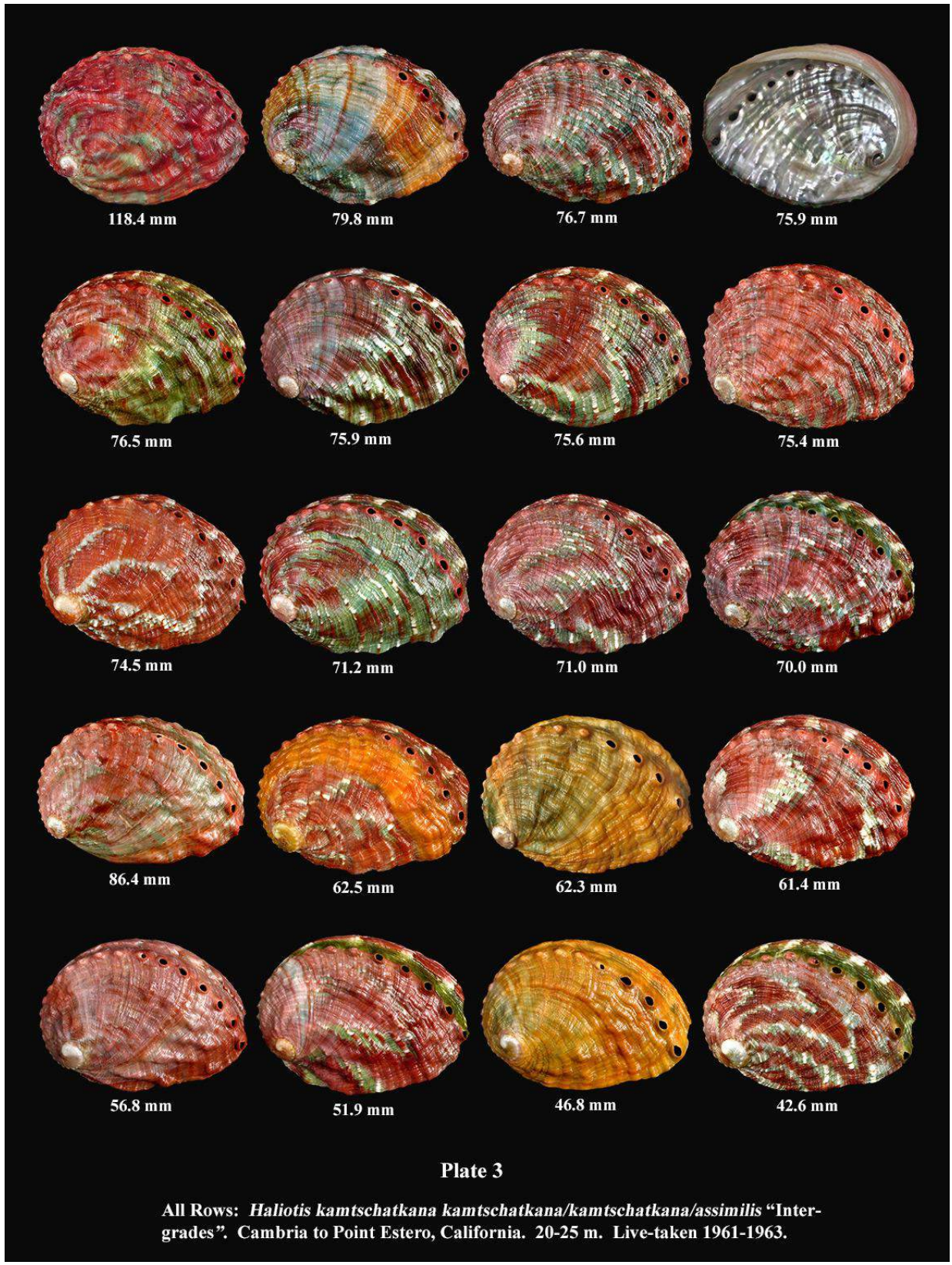

Plate 3

All Rows: *Haliotis kamtschatkana kamtschatkana/kamtschatkana/assimilis* "Intergrades". Cambria to Point Estero, California. 20-25 m. Live-taken 1961-1963.