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Notes from the Editor

In this issue of California Fish and Game we have articles featuring three marine species. Important past and present components of the recreational and commercial fisheries of the Pacific, all are affected by threats from overharvesting, incidental take and loss of habitat. The degree to which these threats are exacerbated by the changing climate has yet to be realized, but events such as El Niño, does appear to increase risks, at least with Chinook salmon. These articles provide information useful to fisheries managers and should be helpful for future recovery efforts.

This is the final issue of volume 103 of the Journal, which has been continuously published quarterly for 103 years. The subject matter index, author index and list of reviewers for this volume are provided for your information as well as for historic narration. In case you're interested, the Journal is currently distributed through library subscriptions to 38 states and 26 countries, plus our online presence, where we are pursuing increased exposure through web-based search indexing platforms.

The Department said goodbye to its long-time Chief Deputy Director Kevin Hunting, who retired in mid-February. As the Chief executive for a state Department with 2,400 employees and an annual budget of $411 million, Kevin was responsible for all facets of Department operations, planning, and management. Prior to becoming the Chief Deputy, Kevin was Deputy Director of the Ecosystem Conservation Division, Acting Regional Manager of the South Coast Region, Chief of the Habitat Conservation Planning Branch, plus Keven held private sector consulting positions in conservation. A birder, Kevin will now have ample time to add to his Life List and pursue his other interests knowing his accomplishments will have lasting benefits to the natural resources of California, and ensure him a legacy of leadership in conservation.

Changes to the Editorial Staff includes the retirement of Russ Bellmer, and the pending resignation of Dave Lentz as he finishes up his last reviews. Both have provided expertise in native and anadromous fish and have led numerous reviews over the years, helping the Journal maintain its high standards for publication. We also bid farewell to Nina Kogut from the Marine Region. Thank you all for your professionalism and generosity. We welcome to the Editorial Staff Jeff Rodzen and Jeff Weaver from the Fisheries Branch, Ken Lindke from the Northern Region, and Dan Skalos from the Wildlife Branch. Welcome and thank you for volunteering. I'd like to thank all the Associate Editors and reviewers who contribute their time and energy, without compensation, this past year to help make the Journal a highly respected source for scientific information on California's fish and wildlife species.

Armand Gonzales
Editor-in-Chief
California Fish and Game

California Fish and Game 103(4): 173-176; 2017

New depth record of the Thorny stingray (*Urotrygon rogersi,* Jordan & Starks, 1895) in the Gulf of California, Mexico

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Key words: depth record, Thorny stingray, *Urotrygon rogersi*, Gulf of California Mexico

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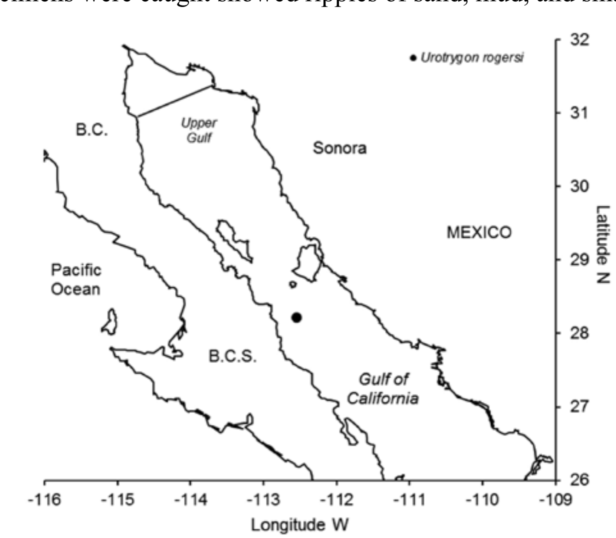
The thorny stingray, *Urotrygon rogersi* (Order Myliobatiformes, Family Urotrygonidae) is a benthic-demersal species endemic to the eastern Pacific Ocean with a distribution from Magdalena Bay, Baja California Sur, Mexico, into the Gulf of California and south to Ecuador (Robertson and Allen 2008). This species is not of fishing importance, however it is common in the Gulf of California as part of the marine fauna of the Cortes and Panamic Provinces (Acevedo-Cervantes et al. 2009; López-Martínez et al. 2010). *U. rogersi* inhabits soft lime and sandy clay bottoms, frequently buried for long periods. The distinctive characteristics of the thorny stingray are a poisonous spine and dorsal denticules arranged in parallel lines, pointed snout, light brown color with no distinctive marks (McEachran 1995). Information is available related to sexual maturity and reproductive cycle (Mejía-Falla et al. 2014; Mejía-Falla and Navia-Cortés 2012), and feeding habits (Navia-López 2009). Castro-Aguirre et al. (1999) described thorny stingrays as being a stenohaline species, typically reported in the neritic zone, most frequently from 2 to 15 m in depth. The occurrence of *U. rogersi* had been recorded to a maximum depth of 30 m (Robertson and Allen 2002), and is frequently found amongst the by-catch fauna from deep-sea shrimping nets. This study documents the new depth record of the thorny stingray caught while bottom trawling, extending its presence to 235 m, which is 205 m deeper than previously reported (Robertson and Allen 2002). Identified by the *IUCN Red List* as "Data-Deficient," this contribution provides new knowledge of the distribution of the thorny stingray. Conservation and management will benefit as a result for this demersal fish in a deep zone scarcely explored.

The specimens were caught on a research cruise on-board the B/O BIP XII in the Gulf of California in September 2005. This prospection had the purpose of locating potentially exploitable crustacean species for commercial purposes in the deep-seas (depths from 50 to 340 fathoms). The project was developed by Centro de Investigaciones Biológicas del Noroeste (CIBNOR).

Samples were taken with a bottom trawl 40 m long, with 5-cm mesh size, operated astern at variable depths from 230 to 460 m. Fishing hauls lasted one hour of effective trawling. Temperature and oxygen in the water column were measured with a CTD (Conductivity, Temperature and Depth) SEALOGGER SBE-25 (Bellevue, Washington, USA). After each haul, the corresponding samples were taken and preserved frozen for on-land processing in the Fisheries Laboratory at CIBNOR, Guaymas, Mexico. Upon landing, the thorny stingray specimens were separated and identified following McEachran (1995), Robertson and Allen (2002), and Nelson (2006). Each specimen was measured for total and disc length using a conventional ichthyometer to 1-mm precision and weight using a conventional balance of 0.1 g precision. Reference organisms were fixed with 10% formaldehyde and preserved in 70% ethanol.

The two thorny stingrays caught in the middle of the Gulf of California (28°13'1" N; 112°33'3" W) at a depth 235 m (Figure 1) measured 225 and 210 mm total length (160 and 140 mm disc length) and weight of 53.2 and 44.3 g, respectively. The bottoms where these two specimens were caught showed ripples of sand, mud, and small hard substrate.



Mexico (28° 13' 1" N, 112° 33' 3" W).

FIGURE 1.—Area of the stingray *Urotrygon rogersi* caught in Gulf of California, Mexico (28° 13' 1" N, 112° 33' 3" W).

In this study the two specimens of *U. rogersi* (Figure 2A, 2B) were caught at deeper waters than historically recorded (30 m), increasing the reported bathymetric distribution notably by at least 200 m. The depth amplitude in the species also allowed adding information regarding temperature and dissolved oxygen requirements, a function of the thermocline, records that are generally lower than in the coastal zone (Acevedo

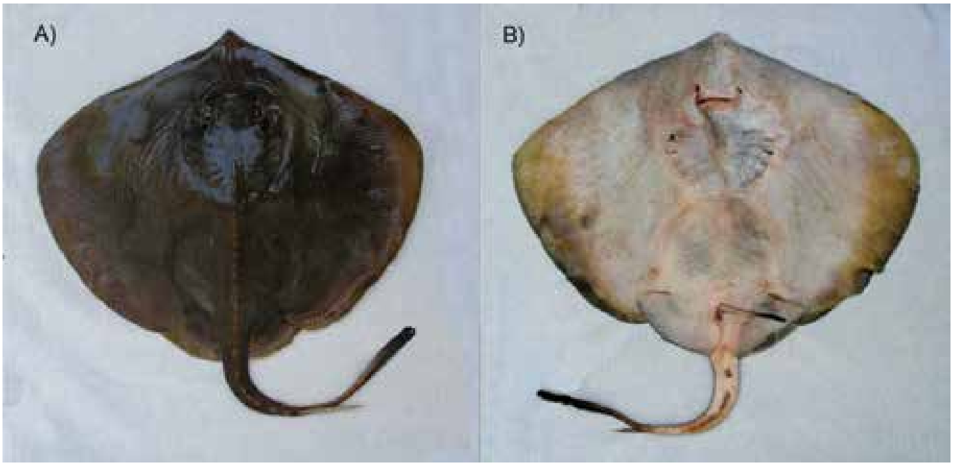


FIGURE 2.—Dorsal view (a) and ventral view (b) of *Urotrygon rogersi* caught in Gulf of California.

et al. 2009). The temperature and dissolved oxygen recorded in the zone where the thorny stingrays were caught (12°C and 2 mg/L respectively) indicate that this species has the capacity to be more tolerant (Figure 3). Robertson and Allen (2002; 2008) had documented that *U. rogersi* was generally found at depths from 2 to 30 m in sandy bottoms, whereas López-Martínez et al. (2010) documented *U. rogersi* being distributed along the continental shelf, and often found in shrimp nets. Coastal species that are distributed along the continental shelf will benefit when at depths greater than those of the shrimp trawls, giving them, perhaps a fraction of the population, the opportunity to avoid the effects of this activity, also benefiting their conservation.

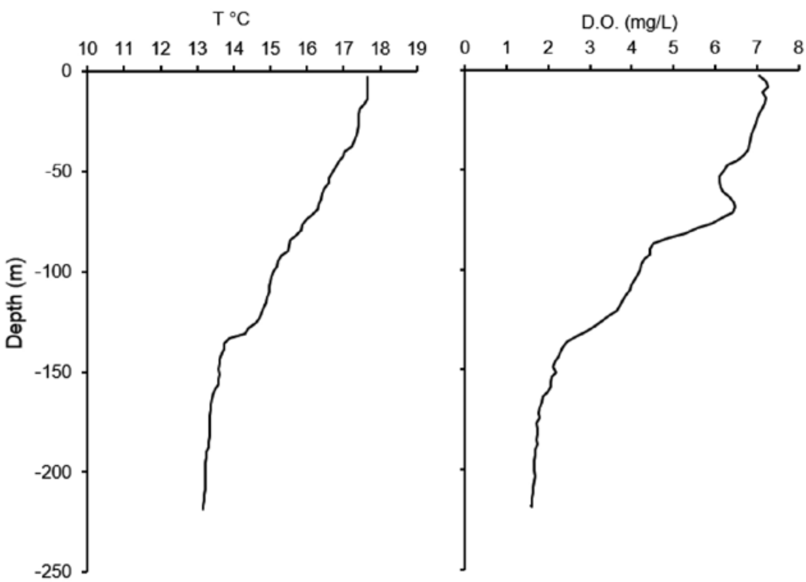


FIGURE 3.—Temperature (°C) and dissolved oxygen (mg/L) profiles of the species caught area.

Our study indicates that *U. rogersi*, previously recorded as typical of the coastal zone, is a species capable of penetrating other deeper areas. This kind of information is of vital relevance for a catalogued species with little knowledge.

Acknowledgments

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Impacts of El Niño on Adult Chinook Salmon (*Oncorhynchus tshawytscha*) Weight in the Gulf of the Farallones from 1983 to 2015

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Key words: Chinook, El Niño, Farallones, reduction in weight, *Oncorhynchus tshawytscha*

Chinook salmon (*Oncorhynchus tshawytscha;* hereafter, Chinook), is a species that has evolved to cope with the highly variable oceanic and freshwater environments of the Pacific Northwest, and responds to large changes in those environments in equally dramatic fashion. Here, some of the effects of El Niño on Chinook as they migrate through the Gulf of the Farallones (GoF), central California Current System, are examined. The southernmost portions of Chinook are those that spawn in the Sacramento-San Joaquin River system (Central Valley of California). They pass through the GoF as adults returning to spawn; their progeny out-migrate through the system as juveniles. Chinook in this system have four distinct runs: fall, late-fall, winter, and spring (Boydstun et al. 2001). While all the runs were probably abundant historically, large-scale habitat changes have reduced populations almost entirely to fall fish, facilitated by production in hatcheries. Natural spawning runs have fallen to such low levels that winter Chinook are listed as Endangered and spring Chinook as Threatened under both the U. S. Endangered Species Act (ESA) and the California Endangered Species Act (CESA). Also fall and late fall Chinook are considered a species of concern by the National Marine Fisheries Service. Herein, we analyze annual variation in body weight of returning adult Chinook, and its relation to the food web in the GoF as affected by El Niño-Southern Oscillation (ENSO), a major driver of California Current System variability (Checkley et al. 2015). El Niño is the positive phase of ENSO, an irregularly occurring change in oceanic conditions affecting the equatorial Pacific region, and leading to the appearance of unusually warm, nutrient-poor water and increased precipitation along the western coast of North and South America (NOAA 2017; Wang et al. 2017). The changes in water temperature and nutrients have a marked effect on a number of important anadromous and marine fishes, especially through reduced forage (Glantz and Thompson 1981; Ainley et al. 2014, 2015). Among the effects are increased mortality and changes in migratory patterns of fishes such as salmon, albacore (*Thunnus alalunga*), and bluefin tuna (*T. orientalis*) (CDFW 2017, PMEL 2017, Kilduff et al. 2015, Dufour et al. 2010). Southern species are found much farther north, especially market squid, Pacific jack mackerel (*Trachurus symmetricus*), and California barracuda (*Sphyraena argentea*) (PMEL 2017). Marine mammals and seabirds also experience dramatic reductions in reproduction and increases in mortality (Benson et al. 2002, Parrish et al. 2007, Ainley et al. 2018, CDFW 2017).

We tested the hypotheses that the strength and occurrence of an El Niño event would be linked with (1) Chinook seasonal dressed mean weights from the commercial fishery from May to June between Bodega Bay and Monterey (PFMC 2017), and (2) the Sacramento Index (O'Farrell et al. 2013), which is an index of Sacramento River fall Chinook adult ocean abundance that includes both catch and escapement using correlation matrices. El Niño events were defined by use of the Oceanic El Niño Index (NCAR 2017) reflecting the winter of *t*-1 through *t* (which we assign to year *t* for correlation analysis). Chinook dressed weights (fish that are landed with their viscera removed) were obtained from commercial fishery landings, from the nearest statistical area between Bodega Bay and Monterey (PFMC 2017), and were compared to El Niño indices. Dressed weights were not available during the season closures, 2008 to 2010, when the California Fish and Game Commission took emergency action to close all California ocean salmon fisheries (i.e., Salmon Emergency). Also, dressed weights during 2005 to 2007 were not used due to local or partial seasonal closures.

Commercial landed Chinook dressed weight was lower during El Niño compared to non-El Niño years (Figure 1). During strong El Niño winters (1982-1983, 1997-1998, and 2015-2016), as well as the moderate El Niño winter (1991-1992), Chinook dressed weight was 69% of mean weights from other years. These El Niño salmon are known as "snakes" due to their substantially reduced body mass relative to length. The Chinook live weight reduction due to El Niño may actually be larger since the gonads, which should be increasing during May and June and would be expected to be smaller during El Niño, have already been removed before the dressed weights are measured.

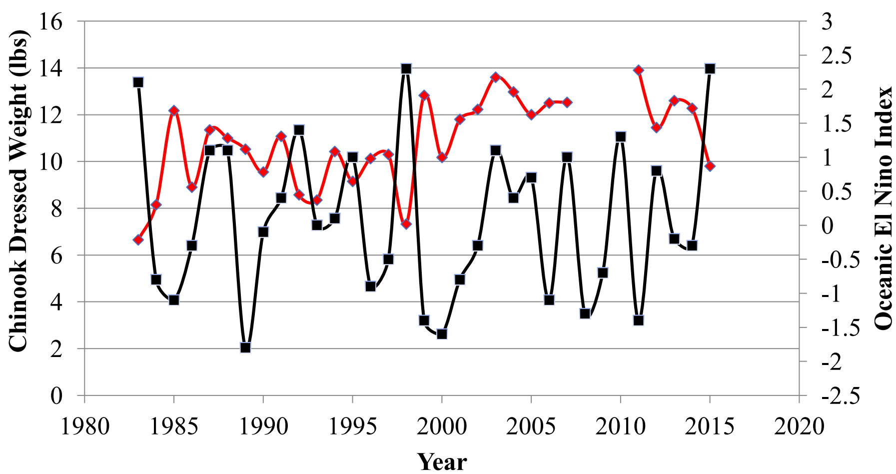

FIGURE 1.—Chinook dressed weight (red) and the Oceanic El Niño Index (black), by calendar year. Note low dressed weights during the strong El Niño winters of 1982-1983, 1997-1998, and 2015-2016 and the moderate El Niño winter of 1991-1992.

Chinook dressed weight from the GoF and the Sacramento Index are correlated at a probability greater than 0.99 until 2004 (correlation between normalized values, r=0.54, df=18; Figure 2). After 2004, the Sacramento Index was forecast at such low levels that fishing seasons were either completely or partially closed and therefore dressed weights were not available. The cause of the these low Sacramento Index numbers was thought to be the result of freshwater and ocean conditions present when these year-classes were entering the ocean as juveniles rather than due to adult conditions at sea (Lindley et al. 2009). These years were not included in our analyses due to fishery closures. After these season closures, the relationship between Chinook dressed weight and the Sacramento Index changed. The dressed weights became high (including the highest and two of the four highest in the series) while the Sacramento Index numbers were very low. It is unclear whether this change is a rebuilding situation from the very low Sacramento Index numbers or a change to a different relationship between Chinook numbers and dressed weight.

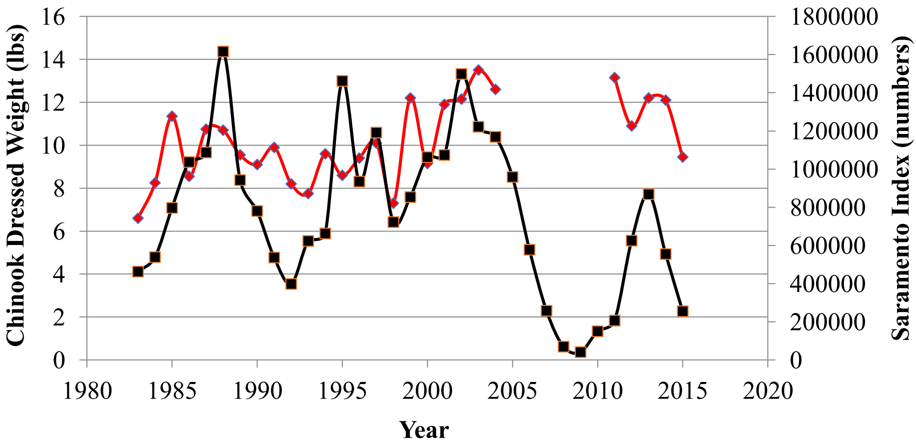

FIGURE 2.—Chinook dressed weight (red) and the Sacramento Index (black), by calendar year. Low values occur in association with the strong El Niño winters of 1982-1983, 1997-1998, and 2015-2016 and the moderate El Niño winter of 1991-1992.

The reduced Chinook dressed weight during El Niño was likely due to a disruption in their normal feeding cycle in the GoF. In non-El Niño years, Chinook move into the GoF beginning in February and March, at which time they are found in waters from Bolinas Point in the north to Pillar Point in the south (Merkel 1957, Adams 2001). They feed almost equally on Pacific herring (*Clupea pallasii*) and northern anchovies (*Engraulis mordax*) in this area (Ainley et al. 2014). April is a time of transition between the earlier nearshore feeding and the offshore feeding that occurs in May and June. Chinook are then found from north of the Golden Gate, i.e., Point Reyes, and offshore to the Farallon Islands. In May and June, Chinook feed on juvenile rockfish (*Sebastes* spp.) and euphausiids offshore along the Farallon Ridge. Sometime between mid-June and mid-July, the Chinook abruptly move shoreward and position directly in front of the Golden Gate, known as the "middle grounds." Here, Chinook feed exclusively on anchovies until they move through San Francisco Bay and into the river system. They stop feeding during their freshwater spawning migration (Boydstun et al. 2001).

Disruption of this feeding cycle appears to have a significant impact, and during El Niño the prey complexes that normally sustain these fish do not form and there is little to feed on (Ainley et al. 2014; Wells et al. 2017). Juvenile rockfish, euphausiids, and herring virtually disappear and anchovies are more dispersed and do not form their usual large aggregations. Juvenile rockfish and anchovies are probably the most important prey because of their high caloric values (Roth et al. 2008). One potential hypothesis is that the disruption of these prey complexes results in the low Chinook dressed weight, and this leads to the reduced condition and fecundity. How this connects to low numbers of Chinook in the Sacramento Index is not understood, but clearly fishing was poor in these years.

For Central Valley fall Chinook, the vast majority of Chinook in the GoF, the impact of reduced weight and Index numbers related to El Niño on the overall long-term population dynamics is small since fall Chinook reproduction occurs largely in hatcheries. That is, hatchery production is maintained at a fairly consistent level across years unless the number of returning fall Chinook adults is very low. In addition, Chinook harvest management tightly controls the ocean fishery to meet a number of objectives (besides Central Valley Chinook escapement, escapement in other systems and ESA concerns). This means that even small numbers of returning adult fall Chinook can maintain average levels of out-migrant juvenile production. The most severe example of this was the complete season closures of 2008-2010. In this way, the fishery has been managed to maintain Chinook populations to meet the various objectives.

However, the situation with ESA and CESA-listed spring and winter Chinook is different since these two runs rely more heavily on natural production of juveniles, even though there are conservation hatchery programs. Therefore, these two Chinook runs may be more vulnerable to El Niño, possibly leading to significantly reduced juvenile production. Spring Chinook, originally the most abundant run in the California Central Valley, now rely on natural production in the upper Sacramento River Valley, with Feather River Hatchery spring Chinook included in the ESA listing unit but not considered in abundance trends (Good et al. 2005). Winter Chinook of the Sacramento River also rely on natural production in the area below Keswick Dam. Both of these runs, spring and winter, have dedicated conservation hatchery programs that produce small numbers of juvenile fishes. These two populations, which are under 10,000 adult fish, but at times dipping into the hundreds of fish (PFMC 2017), are vulnerable to even slight alterations in spawning populations and reduced reproductive capacity. Spawning habitat and freshwater conditions have always been the major concerns as specific risk factors for Central Valley Chinook when considering actions with the long term viability of these ESA and CESA-listed populations. Our analysis suggests that management agencies also need to give more importance to ocean conditions as risk factors in recovery planning.

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Outplanting large adult green abalone (*Haliotis fulgens*) as a strategy for population restoration

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Wild abalone populations are in decline around the globe. Given their high market value, abalone have been targeted for restoration in many areas where they were once abundant. Efforts to restore California green abalone (*Haliotis fulgens*) have had limited success for species recovery. This study aimed to use large (>14cm) adult green abalone as a strategy for restoration. Abalone of this size have few predators and are generally emergent, making them more visible during surveys. Sixty-nine large (average size 16.2 cm) farm raised abalone were outplanted in three batches (May, July and August) in Newport Beach, California, on natural reef structure at a depth of 8.4 m, monitored for 15 months, and then recaptured. Using multiple tagging devices and rigorous monitoring resulted in 40% survival at the end of the study, with 61% of the mortalities occurring within the first 30 days of outplanting, and 46% of the August outplants surviving to the end of the study period. Most of the trackable abalone movements, throughout the study, were confined to a 10 m radius of outplanting areas and 79% (22) of the surviving abalone stayed within 8 m of the outplant areas.

Key words: abalone, adult abalone, *Haliotis fulgens*, outplanting, restoration, restocking, size, stock enhancement

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Abalone populations worldwide have been in decline for many decades (Campbell 2000). Over fishing, illegal harvest, disease and habitat degradation are thought to be the primary causes (Cook 2014). California once supported fisheries for five species of abalone (black, green, pink, red, white) and by 1998 all commercial and recreational fisheries were closed south of San Francisco bay. Rogers-Bennett et al. (2004) found that adult abalone densities in southern California were two orders of magnitude below the estimated minimal viable population of 2000 individuals/ha and at that point, abalone recruitment in southern California had declined 20-fold over the previous decade. Despite 20 years of closed fisheries, populations of all five of these abalone species have yet to rebound on coastal reefs in southern California indicating a need for restoration activities. McCormick et al. (1994) suggested that seeding areas with hatchery raised abalone may be the only means of increasing coastal abalone stocks on a time scale meaningful to fishery managers.

The challenges facing abalone restoration include: captive spawning and rearing, protecting aggregated or outplanted animals from poaching, tracking reproduction, quantifying survival, and maximizing survival of captive-reared abalone in the wild (Henderson et al. 1988, Tegner and Butler 1989, Tegner 1992, Rogers-Bennett and Pearse 1998, Tegner 2000). Reseeding or outplanting projects have most often involved larvae and juveniles (0-100 mm) and have had mixed results around the globe with Japan and New Zealand reporting higher than 50% survival for some projects (Saito 1984, Schiel 1993, Kojima 1981). Results for reseeding or outplanting juveniles in southern California report much lower recovery rates ranging from 0-6% (Tegner and Butler 1985, McCormick et al. 1994, Davis 1995, Chick et al.2013). Quantifying recovery rates is a challenge for comparisons of efforts across time, species and different geographic areas.

Green abalone, (*Haliotis fulgens; Philippi*), are native to southern California and range from Point Conception, California, USA, to Magdalena Bay, Baja California, Mexico, and include the offshore islands (Cox 1962). They were once part of a large recreational and commercial fishery, and have previously been a target for species recovery. The green abalone is listed as a federal Species of Concern (NOAA 2004) and based on historic landings, is estimated to be at less than 1% of its baseline density (Rogers-Bennett et al. 2002). The major threat to remaining populations is their low densities and the possibility of reduced reproduction resulting from the Allee effect (Allee 1931). Low densities of broadcast spawners can lead to poor fertilization and recruitment failure because of the distances between males and females (Babcock & Keesing 1999). Remnant populations are comprised primarily of solitary abalone, many of which may not be contributing to reproduction and are thus functionally sterile (Taniguchi et al. 2013). Results from a drift tube study by Tegner and Butler (1985) indicated that in the absence of local broodstock, a fishery closure alone would not be an effective management policy for the recovery of green abalone populations on the mainland in southern California.

There have been several attempts at restoration of green abalone beginning in the 1970s. Most attempts have involved outplanting small hatchery reared animals generally due to costs associated with raising this slow growing mollusk. Seeding or outplanting results are affected by many variables including condition of the abalone at release, size, planting method, season, as well as site specific conditions including habitat type, food availability, predation, and topography (Saito 1984, Schiel 1993, McCormick et al. 1994). Because of the cryptic and mobile nature of small abalone it is difficult to estimate survival in most studies (Breen 1992, Shepherd & Breen 1992). Juveniles are highly cryptic and are found during daylight hours beneath rocks or in the recesses and crevices; they move freely at night and seldom return to the same location as the preceding day (Leighton 2000). Outplanting activities in Baja California with approximately 20 mm (shell length) green and pink abalone have yielded recovery rates ranging up to 4.7% (Sercy-Bernal et al. 2013). In summary, abalone outplanting has many variables to consider and there has been no formula for "success" that works for all species in all locations.

Translocation of abalone involves aggregating wild animals into one location with the aim of increasing reproductive success. A recent trial involving the translocation of adult California green (*H. fulgens*), and pink (*H. corrugata*), abalone showed that green abalone were not a good candidate for this restoration technique because they exhibited site infidelity (Taniguchi et al. 2013). A previous trial of 4,453 translocated green abalone on the Palos Verdes Peninsula, California was inconclusive due to poaching of the aggregated animals in the second year of the project (Tegner 1992).

Natural mortality of juvenile abalone may vary with location, time, and generally declines with age (Tegner and Butler 1985, Prince et al. 1988, Shepherd and Daume 1996). Initial mortality rates for outplanted juvenile abalone species are quite high and the rates decrease as the abalone grow to larger sizes (Schiel 1993). Saito (1984) found that survival of outplanted abalone increased with seed size in the range of 10 to 50 mm. Outplanting large adults in high densities on isolated reefs seems to be more effective (Coates et al. 2013).

Studies conducted in the 40 years before this project noted issues with the following: tagging (tags falling off, not identifiable); tracking (outplanted animals were not surveyed with enough frequency, were too cryptic, or emigrated off study site); predation (the size of the outplanted animals were vulnerable to multiple predators); poaching; and mortalities from transport shock. With historically limited success in green abalone restoration utilizing juveniles, the aim of this study was to use large (>14 cm) adult abalone for outplanting as a possible restoration strategy and to quantify their survival. This project aimed to also address some of the previous noted issues by using multiple tags, surveying with greater frequency, minimal handling in transport, and removing sea star predators. The use of large animals may act as a model for other abalone species including the endangered white (*H. sorenseni*) and black abalone (*H. cracherodii*) as recommended by Davis et al. (1998). The results are compared with previous restoration studies to determine if larger (>14 cm) outplants yield higher survival rates. The premise is that, large abalone have fewer predators and they are more easily detected and tracked.

Materials and Methods

Study site.—The green abalone outplant site was located in Crystal Cove State Park, Orange County, California, with coordinates 33° 34’ 6.528” N, 33° 34’ 6.528” W. The study site was chosen because it was familiar to the author, too far from shore for shore divers to reach, and was not a well-known recreational dive spot minimizing opportunities for poachers. Surveys were conducted to characterize the composition of the reef, describe the topography, and assess the predator population. Predators of large abalone (>14 cm) in Orange County include octopus (*Octopus sp.*), sea stars (*Pisaster sp.*), and the bat ray (*Myliobatis californica*). The surveys were conducted using two different methods. In one method, an observer conducted two 30 x 2 m band transect surveys and the other method included 30 random 1-m^2 quadrats along two 30-meter transects. Each surveyor collected information on reef composition (continuous reef, boulder, sand, or cobble on every meter), changes in rugosity (change in height of the reef at every meter), percent cover (sessile invertebrates, algal species), the presence of wild abalone, and presence/absence of predators.

The 450 m^2 reef was roughly rectangular and was divided into eight quadrants (approximately 9 x 6 m) using plastic clothesline stretched out across the reef and tied off to cinderblocks. Each quadrant was labeled with floating numbers to make the process of mapping the locations of abalone easier for volunteers. The large Pisaster stars were removed before outplanting and continuously removed during the project period. No octopus were removed from the reef but were present during the entire study, and two bat rays were observed near the reef, one before and one during the study.

Tagging.—Seventy adult abalone were purchased ($38 each) from The Cultured Abalone, a commercial farm in Goleta, California. The average size of the abalone was 16.2 cm (max 17.9 cm, min 14.6 cm). These animals were used as broodstock on the farm and thought to be at least 10 years old. They were shipped in three batches to a holding facility in

San Pedro, California in moist foam and oxygen filled bags and held for up to thirteen days to tag, monitor, and reduce stress from transport. Upon arrival, the animals were measured, sexed, affixed with tags using Splash Zone marine epoxy or cyanoacrylate (Super Glue), and photographed. Of the 69 abalone tagged, 87% (60) were identified as female (Table 1). Since abalone are known for choosing crevices, ledges, and overhangs for their home scars multiple tags were used to make the identifiers visible from any angle. The tags identified which outplant batch the animal was from and had both a unique number identifier (Major Tag) and several auxiliary tags (Minor Tag). Each animal was given a "Major" tag with a number, a color coded zip tie, and up to four other "Minor" tags (Figure 1). The Major tags consisted of a 1.5 cm stainless steel disk with etched numbers; a 2.5 cm white plastic square with printed black numbers; or a 4 cm brass disk with printed black numbers. All of the abalone had a colored zip tie secured through the first or second respiratory pore. PIT (passive integrated transponder) tags were epoxied on the shells of 32 of the animals for the purposes locating the animals using a PIT tag reader. Minor tags consisted of one or more of the following: blue aluminum tree tags with etched numbers; colored plastic bottle caps; white plastic beads with black letters; red plastic key tags with white numbers; stainless steel washers; plastic chain links; and metallic painted plastic jewelry (shiny). No two animals had the same combination of tags. The white lettered beads were the only tag affixed with cyanoacrylate. Knowing that the abalone would be cryptic to the observing volunteer divers, the objects used for tagging were meant to help spot the animals and the combinations of tags helped to identify the animals in hard to see places.

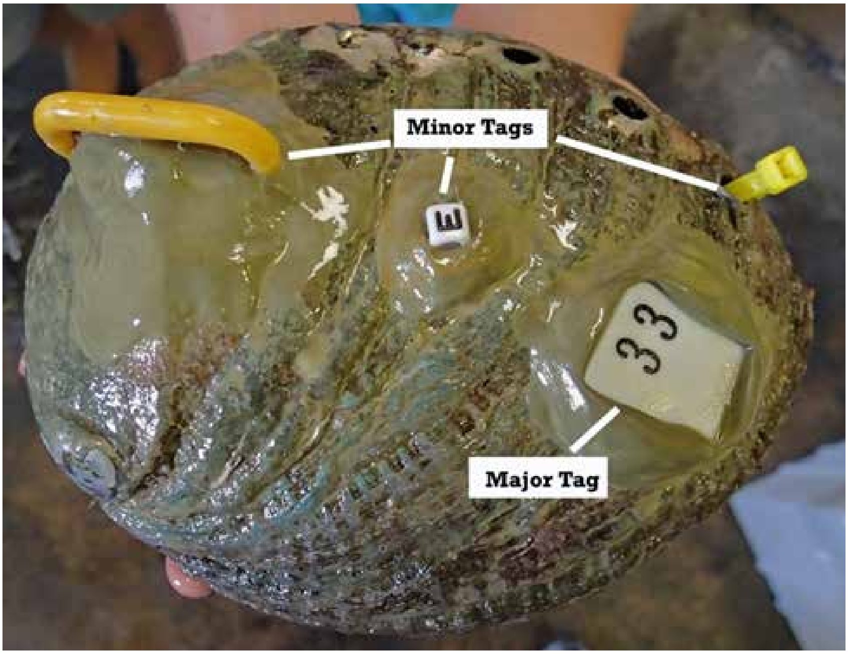

FIGURE 1.—Example of multiple tagging methods for green abalone outplants illustrating "Major" and "Minor" tags. Recorded as Major tag: #33, Minor tags "E", yellow chain link, yellow zip tie, and PIT tag # (in the epoxy).

Following the tagging activity, the animals were placed in rectangular plastic milk crates and submerged in a recirculating seawater holding systems (18 °C) for up to 13 days. The top of the milk crate was covered with plastic mesh so the animals could not crawl out. There was one mortality while in the holding tanks presumably due to stress related to shipment.

Outplanting.—Sixty-nine green abalone were outplanted in three batches in May 2013, July 2013, and August 2013 (Table 1). The animals were monitored for survival for one year after the last outplanting (until August 2014). On the day of outplanting, the animals were checked for health and for any tag loss, the milk crates were put into large coolers with seawater from the holding tanks and transported to the outplant site by car and then by boat. They were in transport for approximately three hours. While on board the boat, fresh ocean water was exchanged with the water in the cooler by bucket. Divers descended to the reef with the milk crates. When on the bottom, the milk crates were turned on their side and four half-sized cinder blocks were zip- tied to each milk crate to weigh them down. The first and third outplant sites offered more ledges and overhangs while the second outplanting area was on the top of the reef just above the other two. All of the locations chosen to place the crates on were within 5 m of each other on the west end of the reef (Figure 2). In accordance with the outplanting permit, as many abalone as possible were recovered from the test site at the end of the study. All animals were measured at the beginning of the study and emergent animals were measured at the end of the study. Volunteers were asked to not share the outplanting location with anyone. Temperature loggers (Hobo) were deployed from 01 April 2013 to 25 March 2014.

Monitoring.—Monitoring began with the first outplanting in May 2013 and concluded one year after the last outplanting in August 2014, representing a 15-month study period. Rigorous monitoring was required to track the newly released animals as they were very mobile. In order to track this movement, the program utilized volunteers. In total, 28 volunteers were trained as abalone observers. Each dive was led by the Get Inspired project biologist and assisted by up to four other volunteer divers. During each dive, a diver was assigned a quadrant number within which to survey the reef for abalone. Every visible tag

TABLE 1.—Proportion, by sex, of green abalone that were outplanted in three batches and their survival in Crystal Cove State Park, Orange County, California. Average size 16.2 cm.

Outplanted			
	Batch 1 5/26/13	**Batch 2 7/22/13**	**Batch 3 8/11/13**
Females	17	21	22
Males	2	1	6
Total	19	22	28
Survival 8/11/14			
Females	7	7	8
Males	1	0	5
Total	8	7	13

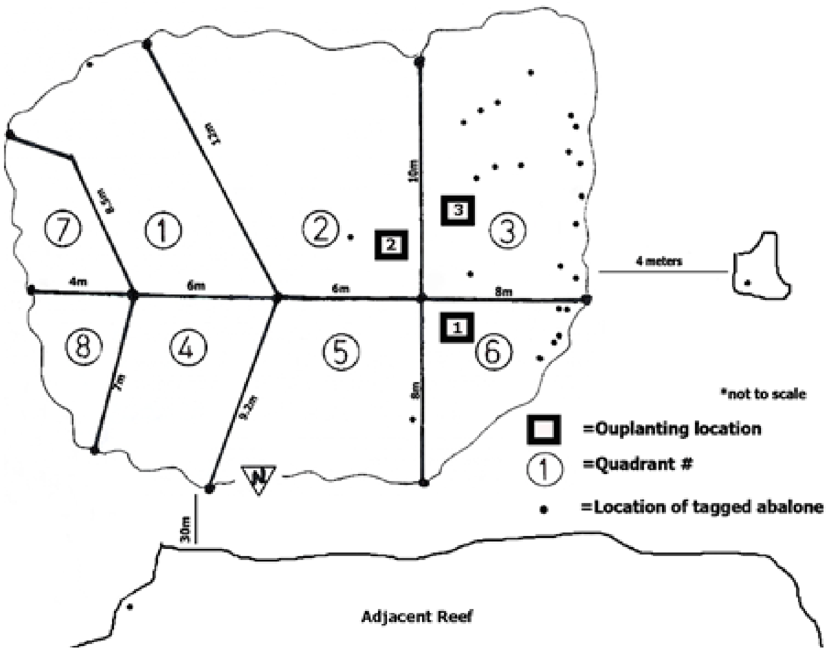

Figure 2.—Map of the relative locations of the surviving abalone created 11 August 2014.

on the animal was recorded and the shells and tags were cleaned with a toothbrush to reduce encrusting organisms. By recording every observable tag, even if a "Major" tag could not be seen, the combinations of other visible tags usually lead to the positive identification of a specific animal. If an abalone could not be positively identified, it was not counted that day. Empty shells and shell fragments were also collected for positive identification.

Over the 15-month (60 week) study period, 64 monitoring dives (approximately 45 min each) were made totaling 260 dive hours. Dives were conducted after each out-planting every 48-hours for approximately two weeks to track the immediate movements of the animals. Monitoring tapered off from every 48-hours to every four days, then once per week, then once every 10 days by the end of the study period. Telescoping mirrors and flashlights were used to look under ledges and in deeper crevices for abalone. A map of the location of each abalone was created/updated after each monitoring dive. An animated map was created, at the end of the project, to illustrate relative movements of the animals throughout the study period. Survival was calculated by finding and counting the actual live animals that were positively identified at the end of the study period.

Results

Site Survey.—The study site is composed of continuous rocky reef approximately 450 m^2 in size and surrounded by sand. The reef is composed of bedrock and roughly rect-angular with dimensions approximately 18 m wide by 25 m long, with the highest point being approximately 2 m from the sand that surrounds it. Changes in contour are minimal on the top of the reef with rugosity being less than 1 m. The south and north ends of the reef are composed of ledges, the west end gently slopes down toward the sand, the east end of the reef is a wall that drops 2.5 m vertically to the sand. The reef was at a relatively uniform depth of 8.4 m on the top of the reef and it slopes on each side to a maximum depth of 11.5 m to the sand on the east end. Due to sea urchin removal activities during a giant kelp restoration project conducted on the reef by the author 10 years earlier, sea urchin densities were low with lots of crevice and ledge space available.

Both site survey methods provided similar results with mature giant kelp (*Macrocystis pyrifera)* covering 10% of the reef providing a 30% canopy, reaching the surface over the reef. Approximately 15% of the reef was covered with pink crustose coralline algae, and articulated coralline algae covered 10% of the reef. Subtidal algae (*Cystoseira osmundacea)* covered 5% of the reef surface and other low lying red and brown alga covered 15% of the reef. The remaining 45% of the reef was occupied by sessile invertebrates including tunicates, bryozoans, worms (Serpulorbis sp.), gorgonians, anemones, and sponges. There were no wild abalone observed on this reef before outplanting. The average temperatures on the reef during outplating were as follows: May-18 °C, July-17.5 °C, August-15.8 °C

Tagging.—With continuous cleaning, the multiple tagging strategy worked well for the study period. Although the abalone routinely were wedged up and under rocks and ledges, the multi tag method allowed for identification of the animals from any angle. Only four of the major tags were lost due to poor epoxy application but the animals could still be identified by their minor tags. By the end of the project period, the brass tags (Major Tag) had tarnished making the numbers unreadable although we could still tell they were brass and coupled with the minor tags, each individual could still be identified. None of the zip ties or cyanoacrylate affixed tags were lost during the project period.

Monitoring and movements.—The milk crates allowed for the abalone to attach to something that could easily be moved, placed in a cooler, and transported to the study site with minimal stress to the animal. Upon release, most of the animals immediately moved out of the crates and even within the period of the dive (approximately 45 minutes) they moved up to 2 m away. All of the abalone left the milk crates within 48-hours of outplanting. Some made their immediate homes inside the cinderblocks that weighted down the milk crates so after the first outplanting batch we covered the cinderblocks so the abalone would be forced out onto the reef. All the abalone were released on the west end of the reef and subsequently 96% of the animals stayed on the west side of the reef within a 10 m radius of their release site, either under ledges or oriented at the sand reef interface during the project period. The farthest distance moved by an abalone was 44 m and the shortest distance moved was <1 m, both of which survived until the end of the project (Figure 2).

The PIT tag reader was only used once and was not effective at locating abalone during that one use. An animated map was created from each survey by compiling location information allowing us to see the relative movements of the animals over the course of the study. This animated map is available from the author.

Survival.—Mortality was closely associated with outplanting events with 61% of mortalities (17) occurring within the first 30 days of being outplanted and 9% (6) mortalities occurring in the first week of outplanting. Being out and on top of the reef (emergent) was not the key factor in mortality because several animals survived through the entire project while in conspicuous places on top of the reef. No direct predation was observed, although we did remove a giant sea star (*Pisaster giganteus*) from the shell of a live abalone. Thirteen mortalities were observed with crushed shells (Figure 3) and the meat gone, with the shell

FIGURE 3.—Example of crushed shells which resulted in 13 mortalities, predator unknown.

fragments found in the same location that the live animal had been previously observed. The shell crushing predator was never observed.

During this 15-month study period, 28 animals (40%) survived (Table 1). We searched adjacent reefs and boulders off the study site. Two abalone were found on a boulder 4 meters away from the outplant reef. They migrated there independently over a two month period. Another abalone ventured across 10 m of sand, across 20 m of reef, then across another 4 m of sand to another adjacent reef. There were 13 animals or 19% of the original 69 that were missing and not accounted for at the end of the project. Some of these animals presumably could have survived. Of the 13 missing animals, seven went missing within 30 days of outplanting and were never seen again. Three of those abalone were missing from the first week of outplanting.

After observing the habitat preferences of the first two batches of outplanted abalone, we chose the third outplanting site to match that of the first. It was 5 m away from the first on the edge of the west end of the reef with many overhangs and ledges. The last batch of abalone (28), outplanted in August, had 46% survival (Table 1). At the end of the 15-month period, eight abalone were retrieved in accordance with CDFW permits. The other 20 were not retrievable due to their positioning on the reef. The average growth of those eight surviving and retrieved abalone was 2.2 mm over the study period. Two of the 13 missing abalone were found dead two months after the end of the study period.

DISCUSSION

Based on findings from Tanaguchi et al. (2013), that green abalone expressed site infidelity when translocated; this survey site was specifically chosen because it was surrounded by sand. It was a disproven assumption that sand would act as a barrier and deter abalone movements. This finding presents a problem for future studies and may shed some light on previous studies where recapture rates were low. Green abalone will leave study sites even if it means crossing expanses of sand. It is possible more abalone emigrated from the survey site and these represent a proportion of the missing animals. Abalone movements and migrations are still poorly understood and continues to be a problem for abalone outplanting/reseeding efforts. Current telemetry will add new knowledge to this question.

Juvenile abalone of all species may move tens of meters, but this tendency decreases with age (Cox 1962, Tutschulte 1976). Adult abalone generally have very limited movements (Shepherd 1973, Tutschulte 1976). Abalone have been known to move considerable distances which has made previous restocking projects challenging and often ineffective (Shepherd 1986, Ault & DeMartini 1987, Tegner & Butler 1989). The majority of the abalone that survived until the end of this project appeared to move very little during the project period, though this also made them easier for divers to find repeatedly. After each survey, a map of the relative locations of the abalone was created. From this, we noted that 22 (79%) of the surviving abalone were within an 8 m radius of the release sights at the end of the project (Figure 2). Many did not appear to move at all from these scars during the entire study. This may be an advantage of using large adult green abalone. In a telemetry study, Coates et al. (2013) mentions a "flight" response when pink abalone were translocated, this was thought to occur within the first 20 days after moving the animals. The reported 61% of the abalone mortalities from this study, occurred in the first 30 days and may have been due to this "flight" response in the initial phase after outplanting.

The fact that the abalone used for this study were farm raised has not been shown to be a factor in their ability to hide (Tegner and Butler 1985, Schiel and Weldon 1987). It appears that abalone have home scars and possibly home ranges for localized movements (Ault & DeMartini 1987, Tutschulte and Connel 1988). Some of the abalone in this study found their home scars right away while others seemed to "roam" throughout the study period. The challenge is to determine how long it takes for introduced/outplanted large emergent adult abalone to get acclimated to their outplanted reef so they "settle" in fast and find a home scar. Ideally, it would be most advantageous to be able to place abalone directly onto their preferred home scar location in hopes that they would stay there when outplanted.

There were at least 13 known abalone mortalities which involved crushed shells and there were many more shell fragments found that could not be identified. Given that these abalone were large with a shell thickness of at least 3 mm, the list of possible predators was small. Very large bat rays and humans are capable of such crushing forces. Giant seabass are capable of both "sucking" them off the reef and inflicting the force necessary to crush the shells (L. Allen, California State University Northridge, personal communication). Often the crushed shell would be found with all the pieces in the same spot that the live abalone was seen just 48 hours before. In October 2013, suspecting poaching as the possible cause of the crushing mortalities, floating signs were posted around the reef warning humans that they were under surveillance and that they were violating the law by taking or killing the animals. It should be noted that within 30 days of the signs being put up, the crushing mortalities stopped. This could be coincidence. It should be noted, that in January 2014 a mortality event (sea star wasting disease), which affected the west coast of North America, resulted in a die-off of all sea star species observed on the reef (Hewson et al. 2014). Sea stars, therefore, were not a predator of concern during much of this study.

Difficulties involved in quantifying the results of outplanting and reseeding efforts make it difficult to make comparisons between studies (McCormick et al. 1994). A summary of abalone outplanting projects around the world, their duration, and percent survival was compiled by Chick et al. (2013). In comparison with those studies, this study has notable survival rates for the project duration (>1 year) and species outplanted, and also used the largest size abalone. Of the studies conducted with larger red and green abalone (40-100 mm) in southern California, survival rates were only as high as 2.8% and the researchers claimed they found no evidence of size differential in survival (Tegner and Butler 1985, Tegner and Butler 1989, Davis 1995). Although survival may be quantified using several different methods, it is important to note that the survival rates reported for this study are actual, not estimates. Each animal counted as a survivor was physically observed.

The frequency with which the animals in this study were surveyed was an advantage for monitoring their survival and it may have been the key to the high recapture rates. We were able to observe their movements regularly (at most every 10 days). With the success of tracking and survival of the animals in this study, it is evident that the strategy of using larger animals for restocking green abalone is worthy of further study. The survival rate for this project is notable and far exceeds survival rates in other studies with green abalone. The animals used in this study were estimated to be at least 10 years old (ranging in size from 14.6 cm to 17.9 cm) by the farmer from whom they were purchased. The costs associated with raising them to this size may be great but there have been decades of attempts to restock. One expensive project may be worth 30 or more failed larval or juvenile outplanting attempts. Perhaps, outplants could be clustered to create reproductive "colonies". The animals used in this study seem to be the largest used in a California abalone restocking/outplanting study. We are currently spawning wild abalone to repeat this test in a future study in several different locations and may include animals 10 cm to 14 cm.

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The Relative Maturity Of The Chinook Salmon Taken In The Ocean Along The Pacific Coast.

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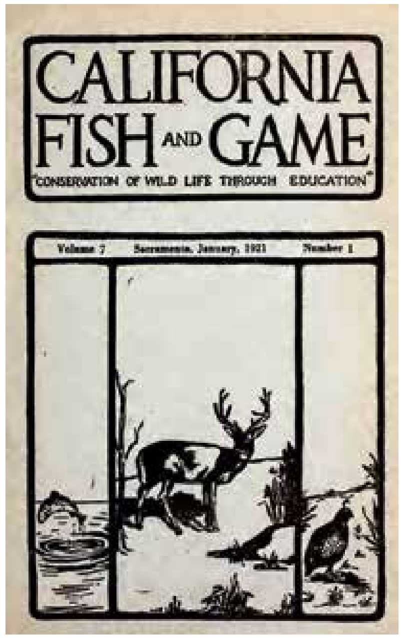

This paper is in the nature of a preliminary report dealing with the maturity of the chinook salmon taken by troll and purse-seine in the ocean along the Pacific Coast, and is presented for the purpose of making immediately available some of the results of the investigation. It is also believed that the method used for determining the relative maturity is new and may be of value to others engaged in similar investigations. A later report will give in detail the data upon which the conclusions presented in this paper are based, and will discuss several topics treated very briefly, or omitted entirely from this paper.

The amount of trolling and purse-seining for chinook salmon along the Pacific coast has increased enormously during the past few years, especially along the northern coast of California, the coast of Oregon, and off the mouth of the Columbia River. To anyone who has observed even casually the fish thus taken in the ocean it is perfectly apparent that a great proportion are immature and it is a point of considerable interest and practical importance to know just what percentage are immature and the relative degree of immaturity. The determination of the age by means of scale studies will not, alone, give a sufficient index to the degree of immaturity since there is such a wide range in the age at which these fish reach the spawning stage—from two to six years. If the percentages of individuals of different ages among the mature fish were constant, it would be possible, from a determination of the percentages of fish of different ages taken by troll and purse-seine in the ocean, to estimate the percentage of fish of different degrees of maturity. This, however, is not the case. The percentages of fish of the various age-groups vary greatly at different times among the mature fish and also among those taken in the ocean. Presumably these variations are due quite largely to racial differences but our present knowledge of the various races of chinook salmon is quite too limited to aid in segregating the races from mixed lots. Even if our knowledge of the races were complete it might well be that they could not be identified and segregated accurately and fully enough to serve the purpose. It is apparent that some other means than the determination of the age is necessary in order to learn the percentages of mature and immature fish taken in the ocean and their relative maturity.

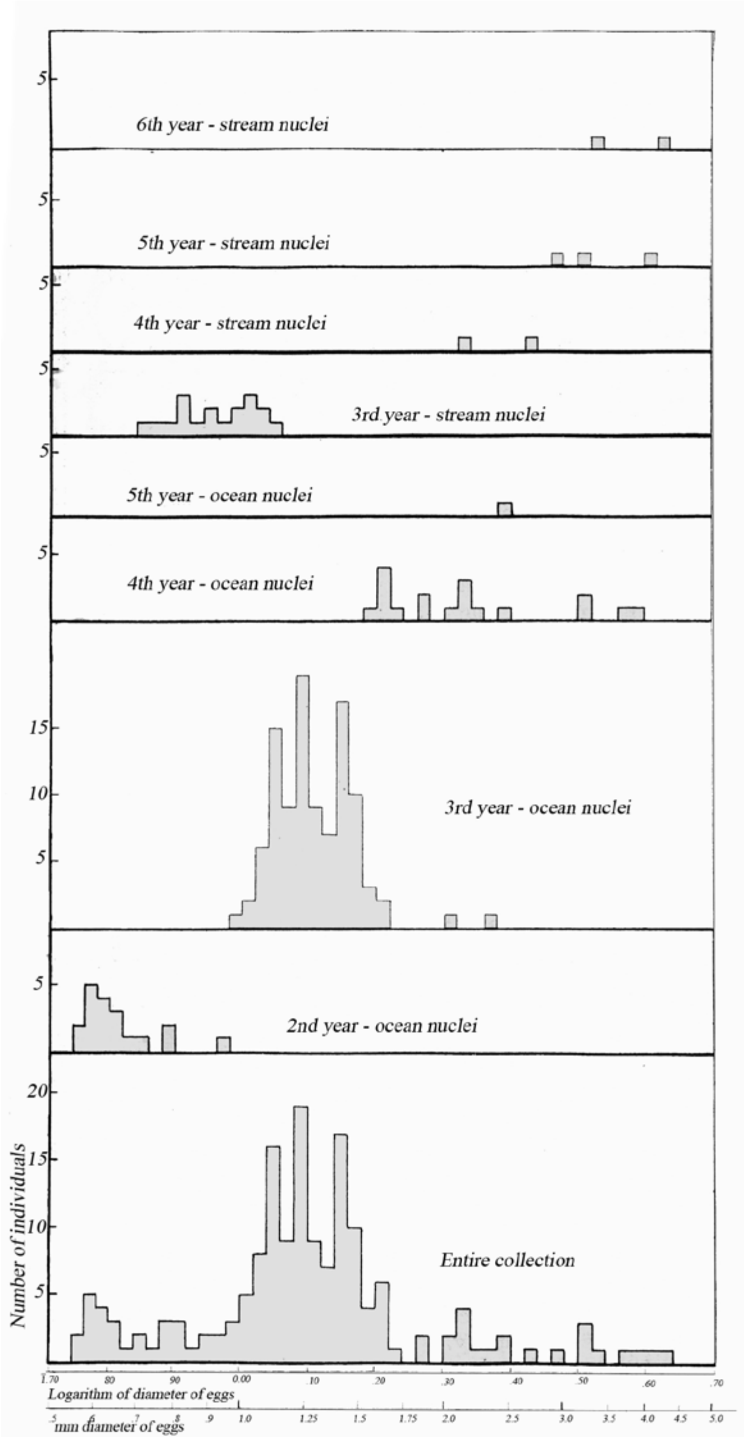

FIGURE 8.—Histogram showing frequency-distribution of 163 female salmon taken by troll off the mouth of the Columbia River, May 8, 1919, based on the logarithms of the diameters of the eggs.

The method which has been developed for determining the relative maturity is based upon variations in the size of the eggs. Obviously this can be applied only to the females and no method has yet been devised for determining the relative maturity of the males. The percentages of males and females found among the mature fish of the various age groups will give some basis for estimating the percentages of mature and immature males from the determination of the relative maturity of the females, but a discussion of this topic must be reserved for the complete report. It is sufficient to state here that, while there is a tendency for the males to mature somewhat younger than the females, the error which would result from assuming that the proportions of fish of similar degrees of maturity were equal in the males and females would not be serious.

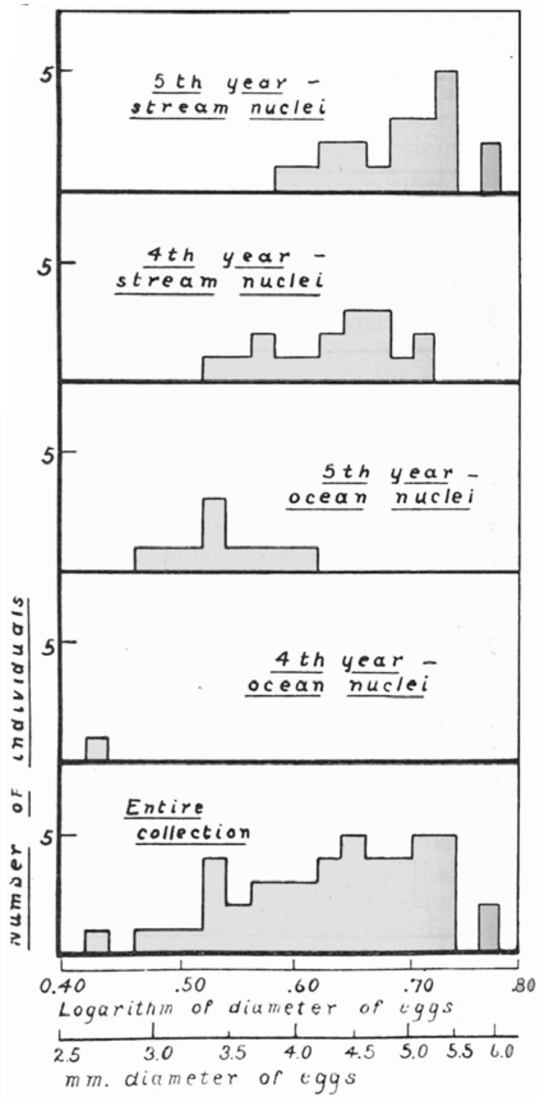

FIGURE 9.—Histogram showing frequency-distribution of 48 females taken by beach seines and wheels near Warrendale, Oregon, June 16, 1919, based on the logarithms of the diameters of the eggs.

Superficial examination of the eggs found in the females taken in the ocean shows that there is a wide diversity in the size and, further, that several more or less distinct size-groups are distinguishable even without careful measurement. It is a natural assumption that these various sizes of the eggs indicate different degrees of maturity. A careful study of several collections of fish taken within the Columbia River and by troll off the mouth of the Columbia, in Monterey Bay, California, and along the northern coast of California confirms this assumption and shows that, by means of a study of the variation in the size of the eggs and a determination of the age by means of the scales it is possible to distinguish, with certainty, in many cases, and with reasonable probability in most, between fish which would have spawned during the year in which they were taken and those which would not have spawned for at least one more year. The distinction between fish which would not have spawned for two years is not quite as definite but in some collections the interpretation is clear.

In studying these collections the age has been determined by the usual method of scale study. The size of the eggs has been determined by measuring ten of each sample and taking the average. The larger eggs—those over 1 mm. in diameter—were measured in a simple device which consists essentially of a small trough, V-shaped in cross-section and with closed ends, which is graduated in millimeters. In use this is partially filled with water, the eggs are placed in a row in the bottom of the trough, and then are carefully pushed up to the zero end of the scale by means of a small piece which fits the bottom of the trough and on which is graduated a vernier enabling one to

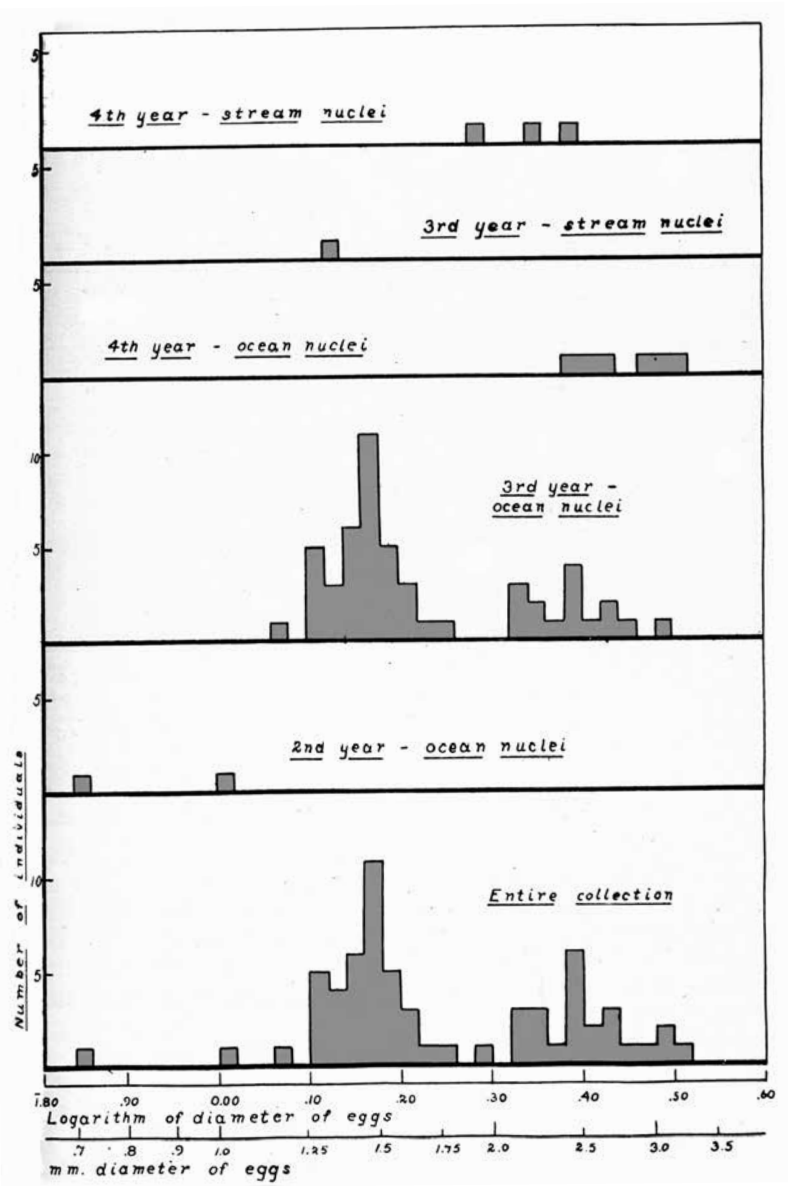

FIGURE 10.—Histogram showing frequency-distribution of 63 females taken bty troll in Monterey Bay, California June 19 - 21, 1918, based on the logarithms of the diameters of the eggs.

read accurately to tenths of a millimeter. The measurement of ten eggs by this scale gives directly, by simply moving the decimal point one place to the left, the average size of the eggs to hundredths of a millimeter. As a matter of faet this measurement is finer than is necessary in the great majority of cases. In preparing eggs for this measurement it is necessary to free them very carefully from the ovarian membranes so as not to break the delicate shell and yet to clear them of all shreds of tissue which might tend to affect the measurement. The smaller eggs—those less than 1 mm. in diameter—were measured by means of a microscope fitted with an eyepiece micrometer carefully standardized. In using this method it was necessary, of course, to measure the ten eggs separately and then the average of these measurements was found.

The tabulating and plotting of these egg measurements has been done on a logarithmic basis—that is, the logarithms of the actual measurements have been tabulated rather than the measurements themselves. The main advantage of this sort of tabulation lis in the fact that proportional variations in size are equally shown independent of the actual size, and it is the relative size of the eggs, rather than the actual diameter, which is significant.

In preparing the tables and charts the classes have been arranged with intervals of .02 in the logarithm of the diameter of the eggs. This signifies that the mid-value of each class is 4.713 percent greater than that of the class next proceeding.

The following collections have been used in the preparation of this preliminary report:

1. 163 females taken by troll off the mouth of the Columbia River, May 8, 1919
2. 68 females taken by troll off the mouth of the Columbia River, June 4, 1919.
3. 48 females taken by beach seines in the Columbia River near Warrendale, Oregon, June 16, 1919. (Warrendale is approximately 150 miles above the mouth of the river.)
4. 48 females taken by traps in Baker Bay, Columbia River, July 3, 1919. (Baker Bay and Sand Island, where the next collection was taken, are both just within the mouth of the river.)
5. 41 females taken by beach seines on Sand Island, Columbia River, July 6, 1919.
6. 101 females taken by troll off the mouth of the Columbia River during August 13 to 17 and September 16 to 17, 1918. (But five of these were taken in September and these have been considered with the August collections.)
7. 95 females taken by troll off the mouth of the Columbia River, August 13, 1919.
8. 63 females taken by troll in Monterey Bay, California, June 19 to 21, 1918.

Full data including scales were taken with each of the above collections. In addition to these the following two collections consisting of eggs alone were studied:

1. Eggs from 144 females taken by troll in Monterey Bay, June 29, 1915.
2. Eggs from 64 females taken by troll near Drake's Bay, August 15 and 16, 1918, and Fort Bragg, July 17, 1918, on the coast of northern California. Scales and data were also collected from the females at the same time the collections of egg samples were made, but the records were not kept so that the egg samples could be referred to the corresponding data and scales. It has been necessary, therefore, to treat egg samples and other data independently.

It will be impossible, in this report, to give in detail the evidence necessary to prove the validity of this method for determining the relative maturity. The graphs will, however, give illustrations of typical results obtained from the measurement and tabulation of the eggs. An examination of the graphs shows that, in the collections of undoubtedly mature fish from Warrendale, the eggs were fairly uniform in size, ranging from about 2.5 to 6 mm. in diameter. The obvious graduation in size of the eggs in the different age groups is probably significant of racial differences, but a discussion of this point cannot be given in this paper. In the case of the fish taken by troll in the ocean the frequency distribution based on egg sizes shown a distinct grouping around several modes which are usually quite well separated.

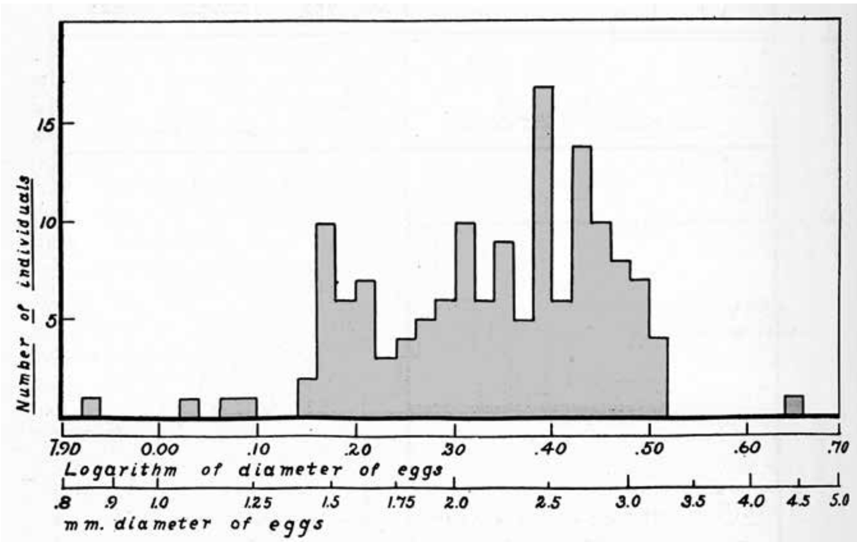

FIGURE 11.—Histogram showing frequency-distribution of 144 females taken by troll in Monterey Bay, June 29, 1915, based on the logarithms of the diameters of the eggs.

Three modes are especially distinct and, in the case of the collections for which age determination were also made, and which have, therefore, been separated into the component age groups (Monterey, 1919, and Columbia River, May, 1919) it is apparent that the group characterized by the largest eggs (above 2 mm. in diameter) is composed chiefly of fish in their third, fourth and fifth years, whose scales show the ocean type of nucleus, and of fish in their fourth and fifth years whose scales show the stream type of nucleus. [The nuclear growth here referred to is that located close to the center of the scales and represents the portion of the scales formed during the first year. The “stream” type indicates that the fish remained in the stream during the entire first year of its life. The “ocean” type of nuclei indicate that the fish have migrated seaward sometime during the first year, usually early.]

The group representing the next smaller size of eggs (1.25 to 1.5 mm.) in diameter is characterized especially by fish in their third year with either ocean or stream nuclei, while the group representing the smallest eggs (.6 to .8 mm.) is characterized chiefly by fish in their second year with ocean nuclei. The size of the eggs in the group having the largest eggs corresponds, in each instance, with the size of eggs in the Warrendale collection and are, therefore, without doubt fish which would have matured during the year in which they were taken.

It is apparent, then, that in general the group characterized by the largest eggs is composed of fish one year older than those composing the group with eggs of the next smaller size, and that these in turn are one year older than those composing the group with the smallest eggs. These differences in the size of the eggs are not dependent on corre-

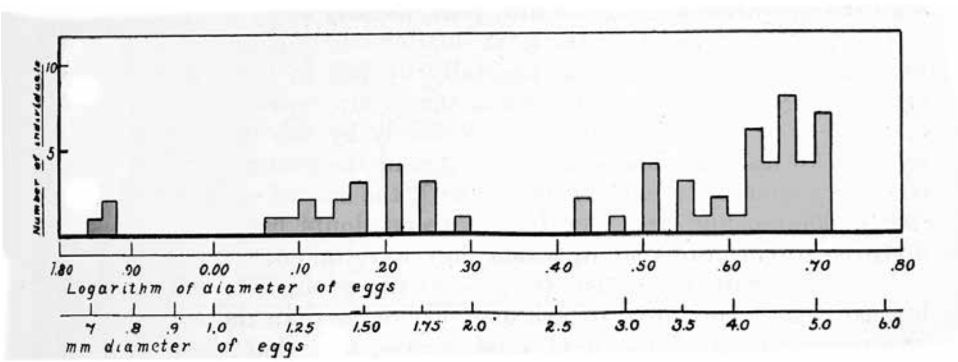

FIGURE. 12.—Histogram showing frequency distribution of 64 females taken by troll near Drake's Bay and Fort Bragg, California, July and August, 1918, based on the logartithms of the diameters of the eggs.

sponding differences in the size of the fish. There is, indeed, a distinct correlation between the size of the fish and the size of the eggs, but, as will be shown in the more detailed report, this correlation is by no means ample and is unquestionably modified by the approach of maturity. Of particular interest and significance is the presence of two groups of individuals within the same age group which may be definitely separated on the basis of egg sizes. This is shown with unusual clearness in the third year fish with ocean nuclei taken at Monterey in 1918. The group with eggs greater than 2 mm. would undoubtedly have spawned during the fall of the same year in which they were taken, while the fish composing the other group would not have spawned for at least one more year. These facts which have been so briefly and incompletely discussed seem to fully justify the conclusion that the size of the eggs is a fairly reliable index of the relative degree of maturity of Chinook salmon.

Without attempting to discuss further the method used for determining relative maturity, a tabular summary will be given of the results obtained by the study of the 10 collections which have formed the basis for this report. It is hoped that further study will increase the accuracy of the results, and it seems probable that some of the percentages given in the table may be somewhat modified by additional investigations. It is believed, however, that the results as given here are fairly reliable. In preparing the table care has been taken to include doubtful cases always with the more mature of the two groups to which they might be assigned. This has been done in order not to exaggerate the degree of immaturitv exhibited by any of the various collections.

From the data contained in these tables the following generalizations may be made:

1. The fish taken in the ocean off the mouth of the Columbia River contain, in the spring and early summer, approximately 70 percent of individuals which will not become sexually mature for one or two years.

2. By the middle of August this condition has changed so that nearly 90 per cent are fish which will soon enter the river for the purpose of spawning. The rate at which this change takes place and the time at which it occurs have not yet been determined, but will be taken up in the later report.

3. A comparatively small percentage of the fish found just within the mouth of the Columbia River are immature. It should be mentioned in this connection that it is only occasionally when unusual tidal conditions obtain that any immature fish are taken inside the mouth of the stream.

4. The fish taken by troll in Monterey Bay in June contain a considerable proportion of immature individuals. The data obtained in 1918 are most reliable, and indicate that only about 40 per cent of the fish taken would have spawned during the same year. The data for 1915 indicates that 75 per cent were mature, but selection may well have taken place in making this collection which, as noted above, consists of egg samples only.

5. The fish taken near Drake's Bay and Fort Bragg in July and August, 1918, contain approximately 30 per cent of immature fish. It is of interest to note that this is an approach to the conditions found off the mouth of the Columbia River in August and suggests that the composition of all the schools found near the coast changes materially during the summer season.

Rich, W. H. 1921. The relative maturity of the Chinook salmon taken in the ocean along the Pacific Coast. California Fish and Game 7(1):12-22

TABLE I.

Composition as to age groups and relative maturity of a collection of 165 females taken by troll off the mouth of the Columbia River, May 8 to 10, 1919.

Age groups	Number of specimens and per cent which would mature during:						Total	
	Year taken		Following year		Second year following			
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Ocean nuclei—								
In 2d year	-------	-------	-------	-------	19	100	19	11.5
In 3d year	2	2	100	98	-------	-------	102	61.8
In 4th year	18	100	-------	-------	-------	-------	18	10.9
In 5th year	1	100	-------	-------	-------	-------	1	.6
Stream nuclei—								
In 3d year	-------	-------	18	100	-------	-------	18	10.9
In 4th year	2	100	-------	-------	-------	-------	2	1.2
In 5th year	3	100	-------	-------	-------	-------	3	1.8
In 6th year	2	100	-------	-------	-------	-------	2	1.2
Totals	28	17	118	71.5	19	11.5	165	-------

TABLE II.

Composition as to age groups and relative maturity of a collection of 68 females taken by troll off the mouth of the Columbia River, June 4, 1918.

Age groups	Number of specimens and per cent which would mature during:						Total	
	Year taken		Following year		Second year following			
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Ocean nuclei—								
In 2d year	-------	-------	-------	-------	18	100	18	26.5
In 3d year	-------	-------	32	97	1	3	33	48.5
In 4th year	-------	-------	1	100	-------	-------	1	1.5
In 5th year	1	100	-------	-------	-------	-------	1	1.5
Stream nuclei—								
In 3d year	-------	-------	10	100	-------	-------	10	14.7
In 4th year	2	50	2	50	-------	-------	4	5.8
In 5th year	-------	-------	1	100	-------	-------	1	1.5
Totals	3	4	46	68	19	28	68	-------

TABLE III.

Composition as to age groups and relative maturity of a collection of 48 females taken by seines and wheels near Warrendale, Oregon, June 16 and 17, 1919.

Age groups	Number of specimens and per cent which would mature during:						Total	
	Year taken		Following year		Second year following			
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Ocean nuclei—								
In 4th year	1	100	-------	-------	-------	-------	1	2
In 5th year	10	100	-------	-------	-------	-------	10	21
Stream nuclei—								
In 4th year	17	100	-------	-------	-------	-------	17	35
In 5th year	20	100	-------	-------	-------	-------	20	42
Totals	48	100	-------	-------	-------	-------	48	-------

TABLE IV.

Composition as to age groups and relative maturity of a collection of 51 females taken by traps in Baker Bay, Columbia River, July 3, 1919.

Age groups	Number of specimens and per cent which would mature during: Year taken		Following year		Second year following		Total	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Ocean nuclei—								
In 3d year	1	100					1	2
In 4th year	24	100					24	47
In 5th year	17	100					17	33
In 6th year	3	100					3	6
Stream nuclei—								
In 3d year			1	100			1	2
In 4th year	4	100					4	8
In 5th year	1	100					1	2
Totals	50	98	1	2			51	

TABLE V.

Composition as to age groups and relative maturity of a collection of 41 females taken by beach seines on Sand Island, Columbia River, July 7, 1919.

Age groups	Number of specimens and per cent which would mature during: Year taken		Following year		Second year following		Total	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Ocean nuclei—								
In 2d year					5	100	5	12.4
In 3d year	1	50	1	50			2	4.8
In 4th year	20	100					20	48.8
In 5th year	8	100					8	19.5
Stream nuclei—								
In 3d year					4	100	4	9.7
In 4th year	1	100					1	2.4
In 5th year	1	100					1	2.4
Totals	31	76	1	2	9	22	41	

TABLE VI.

Composition as to age groups and relative maturity of a collection of 102 females taken by troll off the mouth of the Columbia River, August and September, 1918.

Age groups	Number of specimens and per cent which would mature during: Year taken		Following year		Second year following		Total	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Ocean nuclei—								
In 2d year			1	20	4	80	5	5
In 3d year	21	84	4	16			25	24.5
In 4th year	19	95	1	5			20	19.5
In 5th year	19	100					19	18.5
Stream nuclei—								
In 3d year			2	100			2	2
In 4th year	3	100					3	3
In 5th year	27	100					27	26.5
In 6th year	1	100					1	1
Totals	90	88.3	8	7.8	4	3.9	102	

TABLE IV.

Composition as to age groups and relative maturity of a collection of 51 females taken by traps in Baker Bay, Columbia River, July 3, 1919.

Age groups	Number of specimens and per cent which would mature during: Year taken		Following year		Second year following		Total	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Ocean nuclei—								
In 3d year	1	100	-------	-------	-------	-------	1	2
In 4th year	24	100	-------	-------	-------	-------	24	47
In 5th year	17	100	-------	-------	-------	-------	17	33
In 6th year	3	100	-------	-------	-------	-------	3	6
Stream nuclei—								
In 3d year	-------	-------	1	100	-------	-------	1	2
In 4th year	4	100	-------	-------	-------	-------	4	8
In 5th year	1	100	-------	-------	-------	-------	1	2
Totals	50	98	1	2	-------	-------	51	-------

TABLE V.

Composition as to age groups and relative maturity of a collection of 41 females taken by beach seines on Sand Island, Columbia River, July 7, 1919.

Age groups	Number of specimens and per cent which would mature during: Year taken		Following year		Second year following		Total	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Ocean nuclei—								
In 2d year	-------	-------	-------	-------	5	100	5	12.4
In 3d year	1	50	1	50	-------	-------	2	4.8
In 4th year	20	100	-------	-------	-------	-------	20	48.8
In 5th year	8	100	-------	-------	-------	-------	8	19.5
Stream nuclei—								
In 3d year	-------	-------	-------	-------	4	100	4	9.7
In 4th year	1	100	-------	-------	-------	-------	1	2.4
In 5th year	1	100	-------	-------	-------	-------	1	2.4
Totals	31	76	1	2	9	22	41	-------

TABLE VI.

Composition as to age groups and relative maturity of a collection of 102 females taken by troll off the mouth of the Columbia River, August and September, 1918.

Age groups	Number of specimens and per cent which would mature during: Year taken		Following year		Second year following		Total	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Ocean nuclei—								
In 2d year	-------	-------	1	20	4	80	5	5
In 3d year	21	84	4	16	-------	-------	25	24.5
In 4th year	19	95	1	5	-------	-------	20	19.5
In 5th year	19	100	-------	-------	-------	-------	19	18.5
Stream nuclei—								
In 3d year	-------	-------	2	100	-------	-------	2	2
In 4th year	3	100	-------	-------	-------	-------	3	3
In 5th year	27	100	-------	-------	-------	-------	27	26.5
In 6th year	1	100	-------	-------	-------	-------	1	1
Totals	90	88.3	8	7.8	4	3.9	102	-------

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Subject Matter Index for California Fish and Game 103 (2017)

California Fish and Game 103(4): 208-209; 2017

Author Index for California Fish and Game 103 (2017)

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Information for Contributors

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Literature Cited

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Front—Sockeye (kokanee) salmon in Taylor Creek near Lake Tahoe. Photo courtesy of Peter Hemming.

Rear—Green abalone (*Haliotis fulgens*). Photo by Derek Stein, CDFW.

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