Distribution and Abundance of Juvenile Salmon in Discovery Harbour Marina and Surrounding Area, Campbell River, B. C., During 1996

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DISTRIBUTION AND ABUNDANCE OF JUVENILE SALMON IN DISCOVERY HARBOUR MARINA AND SURROUNDING AREA, CAMPBELL RIVER, B. C., DURING 1996

by

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Chinook stocks in the Campbell River system have shown a sharp decline in numbers beginning in the late 1980's. The construction of the Discovery Harbour Marina in 1988 was put forward as one possible cause for the decline of these stocks. Between May and July, 1996, a field survey was carried out to ascertain the distribution, abundance, and condition of the juvenile salmonids present in the Campbell River estuary, Discovery Harbour Marina, and nearshore area outside the marina. Impacts documented in similar studies in other marinas included loss of rearing habitat due to the construction of the marina, interruption of migration routes and subsequent increased exposure to predation and mortality, and entrapment in the marina basin resulting in increased exposure to poor water quality and high levels of contaminants.

At the conclusion of the study, the greatest impact from the construction of the marina was judged to be the loss of the 5-6 hectares of eelgrass which had occupied the area prior to the construction of the marina. Once the marina was completed, the habitat developed into that of a rocky intertidal and subtidal zone. The loss of this rearing area was compounded by the lack of any suitable areas nearby for the construction of a new eelgrass bed to replace the one that was lost. Although it was not possible to directly link the loss of this eelgrass bed to the dramatic decline in the chinook stocks in this area, it is highly likely that it was a contributing factor when added to other pressures on this stock, including lost spawning areas within the Campbell River.

RÉSUMÉ

Bravender, B. A., S. S. Anderson, and J. Van Tine. 1999. Distribution and abundance of juvenile salmon in Discovery Harbour Marina and surrounding area, Campbell River, B. C., during 1996. Can. Tech. Rep. Fish. Aquat. Sci. 2292: 45 p.

Les stocks de quinnat du réseau de la Campbell accusent depuis la fin des années 80 un déclin marqué. La construction en 1988 de la marina de Discovery Harbour est considérée comme l'une des causes possibles du déclin de ces stocks. Entre mai et juillet 1996, nous avons effectué un relevé sur le terrain pour vérifier la distribution, l'abondance et la condition des salmonidés juvéniles présents dans l'estuaire de la Campbell, dans la marina de Discovery Harbour et dans les eaux côtières aux alentours de la marina. Des études similaires menées sur des marinas ont fait ressortir la disparition d'habitat d'alevinage due aux travaux de construction, la coupure des voies migratoires, qui se traduit par une hausse de l'exposition à la prédation et de la mortalité, et le confinement dans le bassin de la marina, qui accroît l'exposition des poissons à une eau de mauvaise qualité et à de fortes concentrations de contaminants.

À la conclusion de l'étude, nous avons jugé que l'impact le plus grand de la construction de la marina était la disparition des 5 ou 6 hectares d'herbier de zostère qui occupaient la zone avant les travaux. Quand la construction s'est achevée, l'habitat est devenu celui d'une zone intertidale et infratidale rocheuse. La disparition de cette aire d'alevinage a été aggravée par l'absence dans les alentours de zones convenables pour l'aménagement de nouveaux herbiers de remplacement. S'il n'a pas été possible d'établir un lien entre la disparition de l'herbier de zostère et le grave déclin des stocks de quinnat de la région, cette perte est très vraisemblablement à inscrire parmi les facteurs qui influent négativement sur ce stock, comme la disparition de frayères dans la Campbell.

INTRODUCTION

Campbell River has long been renowned for the runs of chinook salmon, (*Oncorhynchus tshawytscha*), which return each year to spawn in its waters. These fish provide income to commercial fishermen and the numerous resorts and fishing lodges scattered coast wide. There has been a dramatic decline in the returns of spawning chinook salmon to this system in recent years.

This reduced escapement of chinook is of concern to both the fishing industry and Fisheries and Oceans Canada. In 1996, it appeared that this decline may have been coincidental with the construction of the Discovery Harbour Marina, which is located near the town of Campbell River on the shores of Discovery Passage (Fig. 1). To investigate this possibility, a project was begun in May 1996 by staff of the Pacific Biological Station, Fisheries and Oceans Canada, Science Branch, in Nanaimo, in cooperation with the Quinsam River Hatchery in Campbell River.

WATERSHED

The Campbell River, located on the east coast of Vancouver Island, drains into Discovery Passage just south of Seymour Narrows. It originates at Buttle Lake and drains an area of 1461 km^2, which is the second largest drainage basin on Vancouver Island. Mean annual discharge for this river is 98 $m^3 s^{-1}$. The largest tributary in this system is the Quinsam River, which joins the Campbell River three kilometers from its mouth and drains an additional area of 280 km^2. There are also a number of smaller streams which join the main rivers, and the average annual flow of the Campbell River at the estuary is 108 $m^3 s^{-1}$ (Bell and Thompson, 1977).

The Campbell River watershed has undergone extensive alteration by man. Between 1947 and 1958, three dams were built by B. C. Hydro. In 1947, the John Hart dam and generating station were built 3.7 km up river from the estuary. The Ladore Falls storage dam followed in 1949 and the Strathcona dam and generating station in 1958. To increase the storage capacity of the system, diversions were also constructed on the Salmon, Quinsam and Heber river systems (Bell and Thompson, 1977). The construction of these dams has led to a shortage of gravel and the loss of chinook spawning habitat within the river, which was documented by Burt and Burns in 1995 in a report for B. C. Hydro.

Historically, the Campbell River estuary has been used by the logging industry to transport and store logs, and to deliver finished lumber products to market. In addition, seaplane terminals, marinas, barge transport and construction facilities, and gravel harvesting have all contributed to dramatically change the original shoreline and configuration of the estuary. In 1996 a management plan was put in place (Witty Planning Consultants Ltd., 1996) to regulate any further developments in the estuary and to facilitate restoration of lost fish habitat undertaken by staff from both the federal and provincial governments.

FISHERIES RESOURCES

For many years the Campbell River system has supported natural runs of chinook (*Oncorhynchus tshawytscha*), chum (*Oncorhynchus keta*), pink (*Oncorhynchus gorbuscha*), coho (*Oncorhynchus kisutch*), and sockeye (*Oncorhynchus nerka*) salmon. This system also supports small numbers of sea-run cutthroat trout, a summer and winter run of steelhead trout, and Dolly Varden char (Burt and Burns, 1995).

In the early 1970's, a hatchery was built on the Quinsam River, and over the ensuing years, this facility has released large numbers of juvenile salmon and trout into both the Campbell and Quinsam rivers. Some of these young fish go to sea immediately while others, largely juvenile chinook, migrate to the Campbell River estuary and nearshore marine foreshore. Here they may remain for up to 3 months, feeding and growing, before moving into deeper water.

Escapement records for chinook salmon are available for both the Campbell and Quinsam rivers, from 1953 to 1996. During this period, the escapement to the Quinsam River has fluctuated, from as low as 25 fish in 1957, before the hatchery was built, to a maximum of 12,112 spawners in 1990. Historically, all the chinook in the Quinsam River have originated from the Campbell River stocks, and the majority of the chinook spawning naturally in the Quinsam River are thought to be hatchery fish, returning to their natal water source.

As the returns of chinook to the Quinsam River increased, the escapement to the Campbell River decreased. Before the construction of the hatchery, escapement in the Campbell River ranged from a low of 750 chinook in 1956 to a maximum of 8,000 in 1965. Between 1977, when the hatchery was built, and 1992, when the first brood spawned after the marina construction returned, escapements dropped to a low of 750 in 1983, increased to 5,100 fish in 1986, and then dropped very sharply to 271 in 1990, 1,500 in 1991, and 819 in 1992. The downward trend in escapement to the Campbell River has continued, to a low of 242 chinook in 1993, 561 in 1994, 319 in 1995, 536 in 1996, and 272 in 1997. This downward trend is also evident in the number of spawners returning to the Quinsam River since 1992, with a low of only 496 fish in 1994. Escapements of chinook for this river slowly increased to 682 in 1995, 744 in 1996 and 2,583 in 1997 (Ewart, pers com). This may be a reflection of increased survival of hatchery fish.

BACKGROUND

The Discovery Harbour Marina was constructed by Fisheries and Oceans, Small Craft Harbours Branch, and Public Works Canada, in partnership with the Campbell River First Nations. The construction of a marina had been proposed by the band in 1972, at a site inside the Campbell River estuary. However, investigations by the federal fisheries found that this area was an important rearing area for juvenile chinook, chum, and coho salmon (Bell and Thompson, 1977). It was decided that this habitat needed to be preserved, and after a number of years of negotiation, the site in Discovery Passage was selected as a satisfactory alternative to building a facility in the Campbell River estuary.

Construction started in 1988 and entailed filling 17 hectares of foreshore and enclosing a further 18 hectare basin with a rubble mound breakwater. The basin was dredged to between two and five metres depth below chart datum. It is now comprised of sand and silt substrate.

The building of this marina presented some unique problems, as Discovery Passage is known as an area of upwelling, swift currents, and whirlpools. This is a result of the flooding of the tide from both the south through the Strait of Georgia, and the north from Johnstone Strait. There can be as much as a two hour delay between the flooding of the tide from the two directions, resulting in a water level difference across Seymour Narrows of up to 1 m. This difference in water surface elevation can produce currents of up to 7 ms^{-1} through Seymour Narrows and 3.0 ms^{-1} in Discovery Passage (Public Works Canada, 1984).

Prior to its construction, engineers estimated that, once this marina was built, the diversion of the water around the breakwater, as the tide ebbs and floods, could result in currents in excess of 1.6 ms^{-1}. Construction was only begun after extensive investigation, including the use of a model over a two year period to simulate the currents which were likely to be produced once this marina was completed (Public Works Canada, 1984).

The Discovery Harbour marina was designed to hold up to 1000 recreational boats and 200 commercial fishing boats. Concrete floats were installed, and a steel wall was built to facilitate the loading of barges and other commercial shipping vessels. A small gas dock and store were also located inside the marina.

During the sampling in 1996, the total number of pleasure craft passing through the marina from May to September was 513. In 1997, there were 560 transient boats and in 1998 this increased to 623. Approximately 40 commercial boats use the marina facilities on a continuing basis, and traffic in and out of the marina also includes barges, and other vessels which use the loading facilities located in the north end of the marina.

PAST RESEARCH

Prior to the construction of the marina, research was carried out by staff from the Department of Fisheries and Oceans, Pacific Biological Station, in Nanaimo, and the West Vancouver Laboratory, to assess the populations of juvenile fish using the foreshore to rear before migrating to sea (Brown et al., 1987). This is an area which was designated as the "transition" zone during the 1982-1986 studies, due to the influence of the freshwater from the Campbell River on the salinity levels. Between 1982 and 1986, this area was sampled with a beach seine with the same dimensions as the one used in the 1996 study. During this time, catches included wild and hatchery chinook and coho from the Quinsam and Campbell rivers as well as chums and pinks of local origin, the Fraser River and other rivers to the south.

The main impact of a marina usually stems from the actual construction and the attendant destruction of intertidal and subtidal habitats. Altering of shorelines when such structures are built can also lead to changes in along shore transport of sediments, erosion of coastal features, and development of new banks and shallow areas (Cardwell et al., 1978).

The possibility of migrating salmon juveniles becoming trapped within marina basins has been raised by several investigators. In their study of Birch Bay Marina in Washington State, Penttila and Aguero (1978) found increased densities and higher total catches of salmonids inside the marina basin, as compared to the sites outside. Studies carried out by Heiser and Finn (1970), also found higher concentrations of pink and chum salmon inside four marinas, as compared to the natural shoreline areas nearby. Whether these structures were delaying the migration of these juvenile fish, due to difficulty leaving the marina, was unknown.

Of concern in other studies was a possible increase in mortality, due to migrating fish being forced out into deeper waters around the breakwaters, or bulkheads, of marinas. Heiser and Finn (1970) reported observing an increase in mortality of salmon fingerlings forced out into deeper water, where they were preyed on by coho salmon smolts and cutthroat trout. The presence of large numbers of resident predatory fish in the marinas, and the increased potential for predation due to crowding, was also of concern (Penttila and Aguero, 1978).

Inadequate flushing inside marinas has been known to increase exposure to poor water quality, by reducing dissolved oxygen levels and adversely altering pH, temperature, and salinity levels. Concentration of suspended solids results in increased water turbidity, and the absence of suitable food organisms could lead to decreased fitness and low growth by the juvenile fish. Exposure to toxic spills is also a known risk inside marinas (Heiser and Finn, 1970).

The habitat disturbance attendant to the construction of a marina may also have an impact on primary production, as shallow sediments, eelgrass, and macroalgae are replaced with deep basins, floating docks, and rip rap substrate (Iannuzzi et al., 1996). The importance of marine littoral areas for the rearing and survival of juvenile Pacific salmon has been well documented (Cardwell et al., 1981; Healey, 1979; Levings et al., 1991).

HABITAT

The area where the Discovery Harbour marina is presently located had previously comprised a shallow bay with a gently sloping foreshore. Prior research had shown this area to be a "nursery " area for juvenile salmonids, with large schools of juvenile pink, chum, chinook, and coho rearing here during the spring and early summer (Brown et al., 1987). This was attributed in part to the presence of a large, unique eelgrass bed which covered 5-6 hectares of the gravel and sand substrate. Eelgrass requires a delicate balance of light and currents as well as an influx of nutrients and suitable substrate in order to survive and flourish (Harrison, 1984). Within Discovery Passage, there is limited habitat available which is suitable for eelgrass to grow and, although it can be propagated artificially, often it is without success.

On the Pacific coast, eelgrass beds extend from Alaska to Mexico, and on the Atlantic coast, from Greenland to North Carolina. It also grows along the coasts of the British Isles, Europe, and Asia. Seagrass meadows are important as nursery grounds for commercial species, including many species of juvenile fish and shrimp, as a food source for migratory birds, to the survival of green sea turtles and many types of shellfish throughout the two oceans. Eelgrass roots bind the sediment and prevent erosion, while the leaves facilitate the deposition of fine sediments, process nutrients, and make them available to other plants (Thayer and Phillips, 1977).

The major food chains within the seagrass beds are based on detritus from the blades. Scientists investigating eelgrass meadows in Denmark concluded that organic detritus, derived chiefly from the decay of eelgrass, was the basic source of nutrition of animals in Danish coastal waters, especially the benthic invertebrates, and that the abundance of fish in Denmark was due chiefly to eelgrass. The blades are also used as food sources by many epiphytic organisms, invertebrates, and fish. Annual productivity in an eelgrass bed has been estimated as high as 500 g C m^{-2} (Phillips, 1984).

Vegetated habitats such as eelgrass beds provide protection for various juvenile fish from predation. In Newfoundland, age 0+ juvenile cod were found to seek out patches of eelgrass almost exclusively, to shelter while rearing (Gotceitas et al., 1997). In Australia, a one year investigation of small fish from eelgrass and unvegetated patches found more species and individuals at the eelgrass sites during every sampling period (Connolly, 1994). On the Atlantic coast, an investigation of two estuaries in New Jersey found species richness to be positively associated with higher habitat structural heterogeneity, and two eelgrass stations showed significantly greater mean species per tow of fish and decapod crustaceans (Szedlmayer and Able, 1996).

ENHANCEMENT

Since 1991, the Quinsam River Hatchery has reared juvenile chinook in seapens moored in the Discovery Harbour Marina. In April 1996, approximately 530,000 juvenile chinook were placed in pens in the southern portion of the boat basin. About 25,300 of these fish were marked with a coded wire tag (CWT), and were adipose fin clipped. They were fed until their release into the marina on May 6, at which time they varied in length from 75 to 101 mm, with an average of 90 mm. They weighed between 4.3 and 11.3 grams and averaged 8.0 grams (Ewart, pers. comm.).

During 1996, between March 14 and April 10, 1996, the Quinsam River Hatchery produced 6.7 million juvenile pink which migrated naturally from hatchery gravel boxes into the Quinsam River. Juvenile trout released from the hatchery between April 12 and May 3 included 20,588 steelhead and 5584 cutthroat. Releases of juvenile chinook during the month of May totaled over 2.6 million.

METHODS

Sites were selected for this study based on their location within the estuary, outside the marina in Discovery Passage, and inside the marina itself (Fig. 1). A full description of these sites is available in Bravender et al., 1997. The study focused on the possible entrapment of juvenile salmon within the marina basin, disruption of normal migration patterns by the barrier presented by the breakwater, reduction in fitness due to decreased food sources, and increased susceptibility to predation.

Sampling was begun on May 2 to 3 using two different nets designed to assess the numbers of juvenile salmon present, both close to shore and offshore in slightly deeper water. The first trip was scheduled before any fish had been released from the hatchery, and at that time, no chinook were found in the estuary, the marina, or the marine nearshore area.

Ten sites (4 in the estuary, 3 outside the marina, and 3 inside the marina) were sampled with a beach seine 13.5 m long and 2.9 m deep. It was fitted with 4.5 m wings of 1 cm stretch mesh, a 4.6 m bunt of 0.6 cm stretch mesh, and rope bridles 15 m long at each end. The net was set using either a 4.9 m aluminum boat with a 50 hp jet drive, or a 5.5 m aluminum craft powered by an 80 hp jet drive. The net was pulled offshore to the full length of the bridle ropes, set in a semi - circle, and slowly pulled back to shore. It was then retrieved by hand. Duplicate sets were done at each site except those sampled in the estuary.

The nine offshore sites (2 in the estuary, 4 outside the marina, and 3 inside the marina), were sampled with a purse seine built to be set and retrieved by hand by a crew of four. This net was 61.5 m long and consisted of a 24.6 m section of 1.8 cm stretch mesh, a 24.6 m section of 1.25 cm stretch mesh, and a 12.3 m bunt section of 0.6 cm stretch mesh. The net was a uniform 6.2 m deep, with a purse line along the entire length on the bottom and a sea anchor attached to the bunt section. A boat 5.5 m in length, powered by a V8 engine and a Hamilton jet drive, was used to make single sets at each site. The seine was loaded onto a platform on the stern of the boat, the sea anchor was tossed over, and the net was slowly set in a circle. Two crew members then pursed the net, using a two speed hand winch, while the remaining two crew members pulled the mesh back on board and concentrated the catch in the bunt of the net.

Both nets were constructed of knotless mesh to minimize the damage to any of the juvenile salmon captured. At most sites the catch was small enough to be counted in its entirety. Where the catch was large, to reduce the damage to the fish, a small subsample was removed with a dipnet and carefully placed in buckets. The remainder of the catch was then counted over by dipnets and released immediately. The subsample which had been retained was identified and counted, and the total catch calculated. Coho and chinook juveniles were identified as unmarked, which included those of wild (or river) origin, and unmarked hatchery juveniles, and adipose fin clipped and coded wire marked (CWT) hatchery juveniles. A random sample of ten or more chinook was retained at most sites for length and weight measurements, which were carried out either on shore at the site or in the boat.

The juvenile chinook were anaesthetized using tricaine methanesulphonate (TMS) at a concentration of 25-40 mg/l. Nose to fork length of each fish was recorded to the nearest millimetre, and they were damp dried and weighed in water to the nearest 0.1 g, using an Ohaus Model No. C305 portable balance. Scale smears were taken from each fish and preserved on adhesive cards. The fish were held until they had recovered from the anaesthetic and were then released at the capture site.

A YSI Model 33 salinometer was used to record salinity and temperature, to depth, at one metre intervals. Ambient oxygen levels were also recorded as percent saturation by an Oxyguard Handy Mk 1 meter, and converted to mg/l dissolved oxygen.

In mid May, 1996, a survey of the marina was carried out by divers from Fisheries and Oceans. A Sony Tr 81 Hi 8 (8 mm) camera was used to record the distribution and abundance of fish populations, as well as sediment and vegetation, along transects in shallow water close to the breakwater, and in the deeper areas of the boat basin. In 1998, a visual dive survey was carried out and any changes in the habitat and vegetation in the boat basin were noted. Particular attention was paid to the distribution and abundance of eelgrass which had been transplanted to benches within the marina basin by Archipelago Marine Research in 1994.

RESULTS

Eight sampling trips were completed between May 2 and July 17, 1996. The physical data, recorded at the sites inside and outside the marina, are summarized in Table 1. Salinities within the marina ranged from 25.8 to 32.2 ‰ , while outside the marina levels between 17.0 and 32.0 ‰ were recorded. Although there was no consistent pattern evident, on some trips the salinities did appear to be slightly higher in the marina, most often in the surface waters. Temperatures varied between 9.2 and 15.0° C at the six sites within the marina, and 9.0 to 14.0° C at the seven sites outside the marina breakwater.

Of major concern were the levels of dissolved oxygen within the marina. These varied from 6.4-11.9 mg/l, which overlapped the range of 5.3-13.5 mg/l recorded at the sites outside the marina breakwater. Fluctuations in the oxygen readings were especially prevalent at beach seine site 3 in the marina where, on several occasions, there appeared to be a strong current entering the boat basin through the northern breakwater. During discussions with engineers responsible for the project, it was noted that the breakwater had been designed to be porous in nature, allowing some interchange of water between the boat basin and the surrounding area.

One hundred beach seines and thirty-five purse seines were done. Samples collected with the beach seine included 9 inside the estuary, 47 inside the marina and 44 outside the marina. Fourteen of the purse seines were completed in the estuary, 16 inside the marina and 5 outside the marina in Discovery Passage (Table 2).

A total of 45,855 juvenile salmonids were captured in all the seines combined, including chinook, coho, pink, chum, cutthroat, and steelhead. Pink and chum only were captured on the first trip on May 2-3, and chinook were absent from the marina, and surrounding area prior to the release of the hatchery seapen fish on May 6. The catches in the estuary consisted mainly of chinook and chum (Table 3, 4; Fig. 2, 3).

The catches within the marina during the project were dominated by large chinook, which appeared to all be hatchery fish from the seapen release in the marina in early May. One beach seine only was done at site 3 inside the north marina breakwater on the second trip as almost 5000 juvenile chinook from the seapens had been captured in the first seine set at this site. During several trips in May, these fish continued to congregate in this area, perhaps influenced by the strong flow of water through the northern breakwater into the boat basin.

The sampling carried out with the purse seine at the three sites within the marina captured mainly the larger seapen chinook. Herring were caught in several samples, and some of the larger hatchery chinook were present in low numbers within these schools. Most of the smaller juvenile chinook were captured with the beach seine close to the breakwater. Pink and chum were much more numerous at the sites outside the marina, compared to those inside. Sandlance and herring, but no rockfish, were also found in both the purse and beach seines outside the marina in Discovery Passage.

No fish were retained during this project, but on July 3 one marked chinook was found dead at site 1. The coded wire tag showed this to be a hatchery fish which had been placed in a gravel box, in the Quinsam River Hatchery. It had been marked with a coded wire tag and released on May 31. This information substantiated other research done in this area, which showed that the juvenile chinook remain within the Campbell River estuary, and the surrounding nearshore marine area, to rear for some time before migrating to sea (Korman et al., 1997).

Juvenile chinook were retained for length and weight determinations, beginning on the third sampling trip on May 13-14. Prior to this, only fish which had earlier been released from the seapens were captured in the marina, and lengths and weights were already available for these fish for the prior week. On the six trips between May 13 and July 17, a total of 410 juvenile chinook were weighed and measured, including 214 fish from sites inside the marina, and 196 from sites outside the marina (Figs 4a to 9b). Mean lengths (mm) ± 1SE, inside the marina, varied from 92.0 ± 1.3 mm on May 13-14 (Fig. 4a) to 113.1 ± 1.7 mm on June 17-18 (Fig. 7a). Mean lengths ± 1SE, outside the marina, ranged between 92.5 ± 3.5 mm on June 17-18 (Fig. 7b) and 105.3 ± 7.2 mm on July 2-3 (Fig. 8b). Lengths only were measured for 44 juvenile chinook captured at the estuary sites, most of which were smaller wild fry (Table 5).

Mean weights (g) ± 1SE, for the juvenile chinook captured inside the marina, varied between 7.9 ± 0.3 g on May 13-14 (Fig. 4a), to 16.4 ± 0.8 g on June 17-18 (Fig. 7a). Outside the marina, the mean weights were between 8.8 ± 1.1 g on June 17-18 (Fig. 7b), and 15.7 ± 3.9 g on July 2-3 (Fig. 8b).

In the purse seine samples, the highest catch per unit effort (CPUE) for chinook was 554 on May 6-7, at sites 11, 12, and 13, inside the marina (Table 3).

The beach seine samples yielded a maximum CPUE for chinook of 1000 on the May 6-7 sampling trip, at sites 3, 4 and 5, inside the marina (Table 4; Fig. 2a). These were all chinook released from the seapens by the Quinsam River Hatchery. The next highest CPUE recorded for chinook was 968 at site 16 in the estuary, again on the May 6-7 sampling.

Pink were caught in the highest numbers outside the marina in the beach seine samples, where CPUE's ranged from 0 to 2057.8 over the eight sampling periods (Table 4; Fig. 2b). The highest density occurred on the May 13-14 trip, when 7518 pink were captured at site 2 in a single set (Bravender et al., 1997).

Chum were captured most often in beach seines, at the sites in the estuary and outside the marina (Table 4; Fig. 3). They usually occurred along with the schools of pink juveniles, but were found in much lower numbers, peaking on the May 6-7 and May 13-14 trips. After May 21-22, the majority had migrated out of the area.

In order to assess whether the juvenile chinook in the marina were able to feed as well as those at sites outside the breakwater, condition factors (K factors) were calculated for the 410 fish for which length and weight data were available, using the formula $K=W/L \times 10^5$ (Meehan and Miller, 1978)(Table 6). At the beach seine sites, the condition factors ranged from 0.71 to 1.34, while the K factors for those chinook captured in the purse seines were between 0.92 and 1.30. For the seven sites outside the marina, K factors were calculated for 196 fish and the overall mean ± 1SE was 1.05 ± 0.01 (Table 7). The mean K factor ± 1SE, for the 214 chinook from six sites inside the marina, was 1.04 ± 0.01. The overall K factor ± 1SE, for all the chinook measured from the 13 sites outside the estuary, was 1.04 ± 0.00.

Assessment of the transplanted eelgrass in 1996 showed that small clumps of between 50 and 100 shoots each had survived in the south end of the marina only. In 1998, divers from Fisheries and Oceans Canada reported that the eelgrass beds were clearly smaller and more sparse than they had been in 1996. It is likely that the eelgrass on the north bench failed to thrive due to the elevation of this bench being above the optimum range for the eelgrass to flourish. During several fish sampling trips in 1996 and during the dive survey in 1998, the rebar to which the eelgrass had been attached for transplant was noted on the north bench well above the lower tide levels.

DISCUSSION

In 1986, Fisheries and Oceans introduced and began to implement a new policy on fisheries habitat. This policy required that there be no net loss in the amount of fish habitat available and an overall increase in its productive capacity (Fisheries and Oceans, 1986). As with all other structures which adversely impact habitat, when the marina was built, consideration was to be given to mitigative and compensative measures to minimize the loss of the eelgrass bed. Although several of the proposed layouts provided for the retention, or possible replacement, of some of this habitat, the final design chosen included the dredging or filling of the entire area.

Construction of any marina within Canada is also governed by marina development guidelines, which are administered jointly by Fisheries and Oceans Canada, and the provincial Ministry of the Environment, Lands and Parks (Fisheries and Oceans, 1995). Consideration is to be given to mitigation or compensation of lost habitat, at the start of any major project which may impact adversely on fish habitat. These guidelines require an inventory of the habitat at risk, its value to fish, and the extent to which it will be altered by the development. In some cases, permission is granted to proceed with a development under specific terms and conditions, even though to do so will result in the harmful alteration of fish habitat. In situations such as this, compensation becomes of primary importance.

Once the marina was finished, there were no large areas in close proximity which could be developed as new eelgrass habitat. However, during the construction of the marina narrow benches, consisting of the original substrate, were left on the inside of the breakwater. These benches ranged in depth from 0.5 m to 2.2 m shallower than chart datum on the north bench to 0.5 to 1.0 m deeper than chart datum on the south bench. In an attempt to replace a portion of the eelgrass bed which had previously existed in the area, Small Craft Harbours contracted with Archipelago

Marine Research Ltd. to investigate the possibility of transplanting eelgrass to these benches.

Prior to the construction of the marina, Public Works Canada had been advised that there was the possibility that eelgrass would not flourish within the basin (Harrison, 1984). However, after consultation with Small Craft Harbours Branch and the Habitat Management Section of Fisheries and Oceans Canada, a decision was made to proceed with the project. Site reconnaissance was carried out by Archipelago staff in October, 1993, of both the marina basin and potential eelgrass donor sites, one in Gowlland Harbour in Discovery Passage, and the other in Baikie Slough in the Campbell River estuary. A comparison of the substrate types, as to size composition, from donor to transplant sites was also completed.

Between March 27 and April 12, 1994, 2525 eelgrass shoots were transplanted from Gowlland Harbour on Quadra Island to 810 m^2 on the bench inside the north marina breakwater, and 750 shoots were transplanted to 540 m^2 on the bench inside the southern marina breakwater. Assessment of these transplants on April 12 and July 6, 1994, showed only 23% of the shoots had survived on the north bench, with the lowest survival in the shallower areas of the bench. In contrast, the plants on the south bench showed a 50% increase in the number of shoots. The study concluded that "Survival of the transplants was depth dependant. Survival was poor in areas less than +0.5 m deep relative to chart datum" (Emmett, 1994). This report recommended annual monitoring for at least another two years.

In several of the dive surveys the divers noted a trench approximately 2 metres wide and 3 metres long with eelgrass on the edge in the south east corner of the boat basin, which may have been the result of large boats within the basin scouring the bottom.

The survey in 1993-1994 by Archipelago Marine Research of the marina basin, inside the breakwater, found a plant community consisting of *Fucus sp.* (rockweed), *Ulva sp.*, *Laminaria saccharina, Costaria costata,* a few bull kelp plants (*Nereocystis luetkeana*), and *Sargassum muticum* (Emmett, 1994). The invertebrate community included barnacles (*Balanus sp.*), cockles (*Clinocardium nuttalli*), horse clams (*Tresus sp.*), red rock crabs (*Cancer productus*), and several octopus (Emmett, 1994). During the 1998 dive survey, it was reported that a mixture of algae, including *Porphyra sp., Laminaria sp.,* and *Agarum sp.,* had also colonized portions of the marina. Barnacles and limpets were observed on the rip rap walls, and in the sandy substrate horse neck clams (*Tresus nuttalli*), and geoducks (*Panope generosa*) were seen. Also evident were sea stars, including *Pychnopodia sp.*, tube worms, tunicates, and a few crabs (MacDougall, pers. comm.).

These surveys showed that the habitat now present in this area was that of a rocky intertidal and subtidal zone. Perch and rockfish had taken up residence, and schools of young of both species were seen inside the marina basin during this project.

This is the fish community also described by Archipelago Marine Research during the eelgrass transplants in 1994, when they found copper rockfish (*Sebastes caurinus*) to be the most abundant fish species, with a mean density of 6 fish per 100 m² in April increasing to 11 fish per 100 m² in July. Other species found included quillback rockfish (*Sebastes maliger*), kelp greenling (*Hexagrammus decagrammus*), tubesnouts (*Aulorhynchus flavidus*), striped seaperch (*Embiotoca lateralis*), juvenile salmon, and young lingcod (Emmett, 1994).

Additional attempts at compensation after the marina was built included the construction of a rock groyne at the mouth of Willow Creek, which flows into Discovery Passage south of Campbell River. At this time, assessment of this structure is still underway, but the habitat created by building this breakwater is far removed from that which was destroyed when the marina was built and will likely be used by stocks other than those from the Campbell River.

Although the sampling during 1996 did indicate that some of the chinook smolts from the Quinsam River Hatchery seapen releases were present inside the marina for some time after their release, the majority had moved out of the area within approximately one week. These fish were captured mainly by the purse seine, off the marina breakwater in the deeper waters of the basin, perhaps indicating a preference for deeper water by these larger smolts. This also appeared to be the case for the herring captured in the centre of the marina with the purse seine. The catches by both the beach and purse seines changed from one sampling trip to the next, and showed that schools of juvenile chinook, pink, and chum salmon, as well as herring, were entering and leaving the marina basin.

Analysis of variance carried out on the lengths and weights of the juvenile chinook captured with the beach seines, inside the marina verses outside the marina, showed a significant difference in the size of the fish captured during only two sampling trips, on June 4-5 and June 17-18 (Table 9). On June 4-5, the smaller fish were inside the marina, whereas on June 17-18, the smaller fish were outside the marina. These results support the hypothesis that the smaller chinook were not trapped within the marina basin. Comparisons of the catch by beach seine inside the marina verses purse seine inside the marina were possible for May 21–22, June 4–5, June 17–18 and July 16–17. In all cases, the larger chinook appeared to prefer the deeper water, and were captured by the purse seines at the sites in the centre of the marina basin. This difference was highly significant on the June 4-5 and June 17-18 trips. Comparisons of the length of the much smaller chinook, captured by beach seine inside the estuary, versus inside and outside the marina, also showed a highly significant difference in size.

There was no quantitative evidence of increased predation on the juvenile salmon caught inside and outside the marina, although during the survey, some fish were captured with bite marks on their fins and sides. This was seen at site 2 outside, and site 5 inside the marina on only a few occasions.

As the range of condition factors (K factor) for the juvenile chinook captured outside versus inside the marina overlapped, there appeared to be no indication that the fish within the marina were entrapped in the structure and experiencing difficulty feeding.

When the marina was constructed a current deflector extending into Discovery Passage was incorporated into the north breakwater (Fig. 1). On most trips, very swift currents were experienced off the end of this structure. In mid May, enormous schools of juvenile salmonids, largely pink and chum juveniles, were found at site 2, north of the deflector, at the confluence of the north marina breakwater and the original shoreline. These observations suggested the possibility that the juvenile fish were experiencing difficulty migrating around the current deflector.

Small schools of salmon smolts were noted on several trips holding in the back eddy to the south of the current deflector, perhaps feeding or waiting to move north past the end of the breakwater. It was also observed that there was often no detectable slack tide in the area off the marina entrance. This made it very difficult to sample with the purse seine outside the marina, and may have made it more difficult for juvenile fish attempting to migrate past this obstacle.

Although the projected currents around the marina were modeled prior to its construction, there have been no field measurements of the actual currents taken since its completion. Despite the swift currents past the marina entrance, from week to week it was found that the fish populations within the marina basin were changing, both in density and species. This fact seems to indicate that juvenile fish, including salmon, herring and sandlance, were able to enter and leave the basin, although it is unknown if the fish experienced any difficulty doing this. However, there was no evidence that they were trapped in the area.

A visit to this site in the summer of 1998 showed that a large commercial development had been built on the upland area adjacent to the marina. When the survey was carried out in 1996, there were much fewer vessels in the basin, and there were only small temporary buildings on the upland area. However, the habitat observed in the marina was already showing signs of degradation. In the deepest parts of the basin, the bottom sediment appeared to be bare of vegetation and unproductive. A thin layer of fuel on the surface of the water was also noted in some areas of the marina. In 1998, the habitat had degraded even further, as observed by the divers.

The levels of dissolved oxygen recorded inside the marina basin during this survey never reached critically low levels. Nevertheless, on many occasions the levels recorded were at, or slightly below, those defined as having "some possibility of moderate risk to aquatic organisms, because it allows some degree of oxygen depression" (Davis, 1975). He defines this as 6.5 mg O_2 l^{-1} or 79-87 % saturation at 0 - 20° C. This occurred at several sites in July, at or near the bottom at 3 to 4 metres depth. However, this was also the case at some of the sites sampled outside the marina during several of the trips. The optimum level of 100% oxygen saturation, as defined in Davis, 1975, was recorded more often at sites outside the marina basin.

When the marina was constructed, one of the sites sampled by Fisheries and Oceans Canada between 1982 and 1986, site 21, was destroyed (Brown et al., 1984). This site was located at the southern end of the eelgrass bed, slightly north of site 6 in the 1996 study. A comparison of these two sites showed that during the earlier study juvenile salmon were present at site 21 consistently throughout the sampling period, likely rearing in this area for two to three months before moving offshore. (Table 8). In 1996, high CPUEs for chum and pink were recorded once at site 6 on the May 2-7 trip. However, the CPUE for most species was much lower throughout the spring and summer. The higher densities recorded at site 2 in 1996 as compared to site 6, also show a strong preference by the juvenile salmon for the habitat north of the marina breakwater. This site was characterized by a large kelp bed just slightly offshore and likely resembled more closely the habitat that was lost when the marina was built. There was much less vegetation present at site 6, which was dominated by gravel and large cobble. During the time of the first study between 1982 and 1986, no seapen reared chinook were produced by the hatchery. However, in 1996, over 500,000 were released in the Discovery Harbour Marina on May 6. This may have resulted in the high CPUE for chinook at site 2 between May 2 and 7.

CONCLUSIONS AND RECOMMENDATIONS

The original hypothesis for this study was that the construction of the Discovery Harbour Marina may have been a contributing factor to the sharp decline in the late 1980's of the stocks of chinook salmon originating from the Campbell River. The results point to a number of possible impacts, including the disruption of migration by the juvenile chinook along the shore, and increased exposure to predation. However, the main impact appears to be the loss of the eelgrass bed and "nursery" area, which existed in this area prior to its construction. Research on eelgrass beds world wide has shown them to be a unique and highly productive habitat, preferred by many species of fish to bare substrate or other macrophytes (Connolly, 1994). Comparison of the catches at sites in this area between 1982 to 1986 (site 21), and 1996 (sites 2 and 6), showed a reduction in 1996 in the densities of all species of juvenile salmon. Catches in 1996 were sporadic, whereas those between 1982 and 1986 appeared to indicate longer term rearing of the juveniles in the eelgrass bed which was present before the marina was built (Table 8). The higher overall densities for all species combined, recorded at sites 2 and 6 during May 1996, seemed to indicate that the juvenile salmon were being crowded into the much reduced habitat now available along this shoreline.

At this time, there has been little compensation for the loss of this eelgrass bed. Even if all the transplanted eelgrass had survived within the marina, there would still be a large net loss of this habitat in this area. As required under the policy for the management of fish habitat (Fisheries and Oceans, 1986), the loss of this eelgrass bed should be compensated for by constructing 5-6 hectares of new eelgrass habitat, dependant, of course, on whether suitable sites on the foreshore can be found. In man-made eelgrass beds, the density of fish and epifauna can equal that in natural beds if the transplants flourish (Fonseca et al., 1990). However, changes in planted beds can still occur up to five years after transplanting (Harrison, 1990). Therefore assessment and monitoring of all compensatory habitat should be carried out for at least five years after transplanting. As the marina basin and adjacent upland area will continue to be developed, it is not recommended to attempt any further restoration or compensation within the boat basin itself.

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Table 1. Summary of physical profiles recorded by trip and zone.

Trip No.	Date	Depth (m)	Inside Marina Salinity ‰	Inside Marina Temp °C	Inside Marina Oxygen mg/L	Outside Marina Salinity ‰	Outside Marina Temp °C	Outside Marina Oxygen mg/L
1	2,3	0	27.9-28.9	9.5-10.0	10.3-10.7	27.4-28.9	10.0-10.3	8.8-11.3
"	May	1	27.9-28.8	9.5-10.0	9.9-10.4	27.1-28.9	9.5-10.5	8.8-11.2
"	"	2	27.9-28.9	9.3-10.2	9.9-10.7	27.2	10.5	7.2-11.2
"	"	3	28.1-28.9	9.2-10.2	10.2-10.9	28.3	10.2	7.9
"	"	4	28.1-28.9	9.2	9.9-11.1	-	-	-
2	6,7	0	25.8 -31.5	10.6-11.0	10.1-10.2	22.9-24.3	10.0-10.8	9.0-10.5
"	May	1	26.0 -28.7	10.4-10.7	10.1-10.2	28.1-30.5	10.1-10.8	8.2-10.7
"	"	2	25.8 -31.5	10.0-10.6	10.5-11.4	28.5	10.1	7.6-10.8
"	"	3	28.2 -30.1	9.8-10.4	10.8-11.6	27.2-30.1	9.6-10.4	10.2-11.7
"	"	4	27.5 -29.0	9.6-10.9	11.0-11.5	27.9-29.0	9.6-10.9	9.7-11.8
"	"	5	27.3	12.0	-	27.3-27.9	9.5-12.0	10.7-12.2
3	13,14	0	27.9-30.5	11.0-12.0	7.7-8.4	25.3-28.0	11.0-12.2	7.8-10.4
"	May	1	29.0-31.2	10.5-11.7	7.9-8.9	26.0-28.2	10.7-12.0	8.2-11.5
"	"	2	28.5-30.0	10.0-12.0	7.7-9.6	25.5-29.5	10.5-12.2	8.3-11.2
"	"	3	29.2-30.8	10.0-11.0	7.9-9.4	29.8	10.6	8.0- 9.6
"	"	4	29.5-30.2	10.0-12.0	7.8-9.7	28.0	9.8	10.3-10.9
"	"	5	29.8-30.0	9.9-10.0	9.2-9.7	-	-	-
4	21,22	0	27.3-28.9	10.7-12.0	8.8- 9.1	26.0-28.9	11.2-11.5	8.2-10.2
"	May	1	28.5-29.0	10.2-11.0	8.7- 9.1	27.5-29.0	11.0-11.2	8.5-10.1
"	"	2	28.3-29.5	10.6-11.3	8.9-10.1	28.0-29.1	11.0	8.7-10.0
"	"	3	28.3-29.9	10.4-11.2	9.2- 9.9	28.0	11.0	8.7- 9.7
"	"	4	28.5-30.1	10.0-11.0	9.5-10.8	28.0	10.9	8.7-10.5
"	"	5	28.8-29.5	10.0-10.8	9.3-11.2	27.3-27.9	9.5-12.0	-
5	4,5	0	28.9-31.1	11.0-13.2	8.7- 9.4	29.0-30.4	9.0-12.5	6.5-10.5
"	June	1	29.4-31.5	11.5-12.5	8.6- 9.5	29.0-30.5	9.3- 11.6	6.7-10.4
"	"	2	29.5-31.0	10.8-12.0	8.8-10.3	29.0-30.0	9.8-11.5	8.1-10.5
"	"	3	29.0-30.1	10.5-12.0	9.1-10.2	29.7	9.8	8.9-10.7
"	"	4	29.0-30.7	10.5-12.2	9.2-10.2	29.8	9.9	8.8-10.7

Table 1 (cont'd).

Trip No.	Date	Depth (m)	Inside Marina Salinity ‰	Inside Marina Temp °C	Inside Marina Oxygen mg/L	Outside Marina Salinity ‰	Outside Marina Temp °C	Outside Marina Oxygen mg/L
6	17,18	0	26.9-30.5	13.8-15.0	7.7-8.4	28.2-28.8	11.8-13.0	8.0- 9.2
"	June	1	27.4-31.2	12.5-14.0	7.8-8.5	28.8-28.9	10.8-13.0	8.0-10.4
"	"	2	27.8-31.2	12.2-13.8	8.3-8.7	28.5-29.0	10.5-12.0	8.2-10.4
"	"	3	28.0-31.2	11.5-12.2	9.2-9.9	29.0-29.2	10.2-11.8	8.0-10.9
"	"	4	28.0-31.5	11.0-12.2	8.1-9.8	28.0-31.5	11.2	8.7-10.6
"	"	5	29.2	11.0	9.8	-	-	-
7	2,3	0	29.5-31.0	13.5-14.8	8.7- 9.6	20.8-29.0	13.0	9.2-10.0
"	July	1	29.2-31.8	13.2-14.2	8.6- 9.6	23.0-29.2	12.4-12.8	9.2-10.1
"	"	2	29.8-32.0	12.5-13.2	9.4-11.8	24.0-30.2	10.0-12.8	8.9-13.5
"	"	3	30.0-31.5	12.0-13.0	9.6-10.6	27.5	12.8	8.6-11.3
"	"	4	30.8-31.5	11.8-12.8	9.6-11.5	28.1-30.8	11.7-11.8	9.8-12.0
"	"	5	31.9	12.0	10.4	28.1	11.6	10.9
8	16,17	0	28.8-31.8	12.2-13.8	6.5- 8.6	17.0-31.8	10.4-14.0	7.1-10.6
"	July	1	29.2-32.2	11.5-12.8	6.4- 8.9	23.5-31.8	10.2-12.0	5.3-10.6
"	"	2	29.0-32.2	11.0-12.4	6.9-11.9	28.8-32.0	10.0-10.8	7.2-11.0
"	"	3	28.8-31.8	10.8-11.5	7.3-11.0	29.0-31.0	10.0-10.5	7.9-11.2
"	"	4	29.0-31.0	10.0-10.8	8.3- 8.9	29.0-31.0	10.0-10.8	9.8-11.6
"	"	5	31.4	11.0	-	28.2	11.0	10.9

Table 2. Number of purse seines and beach seines done during the 1996 marina study by zone (Est.=estuary, I. Mar.=inside marina, O. Mar.=outside marina).

Trip No.	Date	Purse Seines Est.	Purse Seines I. Mar.	Purse Seines O. Mar.	Beach Seines Est.	Beach Seines I. Mar.	Beach Seines O. Mar.	Total Sets
1	May 2-3	2	1	0	0	6	6	15
2	May 6-7	2	3	0	1	5	4	15
3	May 13-14	2	2	1	3	6	4	18
4	May 21-22	2	2	1	1	6	6	18
5	June 4-5	2	2	2	0	6	6	18
6	June 17-18	0	2	0	2	6	6	16
7	July 2-3	2	2	0	2	6	6	18
8	July 16-17	2	2	1	0	6	6	17
Total		14	16	5	9	47	44	135

Table 3. Catches of juvenile salmon per set (CPUE) in purse seines in the Campbell River estuary, within the Discovery Harbour Marina and in the surrounding nearshore marine area by trip.

Trip No.	Date	No. Sets	Pk	Ch	Mck	Uck	Mco	Uco	Cut	Sth
					Estuary					
1	May 2-3	2	0	0	0	0	0	0	0	0
2	May 6-7	2	0	0	0	0	0	0	0	0
3	May 13-14	2	0	0	0	0	0	0	0	0
4	May 21-22	2	3	4	0	2	0	0	0	0
5	June 4-5	2	0	0	1.5	0.5	1	16	0	0
6	June 17-18	0	0	0	0	0	0	0	0	0
7	July 2-3	2	0	17	1	8	0	1.5	0	0
8	July 16-17	2	0	1.5	0	2	0	0	0.5	0

Trip No.	Date	No. Sets	Pk	Ch	Mck	Uck	Mco	Uco	Cut	Sth
					Inside marina					
1	May 2-3	1	0	0	0	0	0	0	0	0
2	May 6-7	3	208.7	0	32.7	521.3	0	0	0	0
3	May 13-14	2	0	0	0	0	0	0	0	0
4	May 21-22	2	0.5	0	2	34	0	0.5	0	0
5	June 4-5	2	0	0	1.5	20	2	56	0	0
6	June 17-18	2	3.5	27.5	5.5	32	0	3.5	0	0
7	July 2-3	2	0	67	0	3	0	1.5	0	0
8	July 16-17	2	0	24	0	4.5	0	0	0	0

Trip No.	Date	No. Sets	Pk	Ch	Mck	Uck	Mco	Uco	Cut	Sth
					Outside marina					
1	May 2-3	0	0	0	0	0	0	0	0	0
2	May 6-7	0	0	0	0	0	0	0	0	0
3	May 13-14	1	0	0	15	186	0	0	0	0
4	May 21-22	1	0	0	0	0	0	0	0	0
5	June 4-5	2	14.5	34.5	0	25.5	0.5	9.5	0	0
6	June 17-18	0	0	0	0	0	0	0	0	0
7	July 2-3	0	0	0	0	0	0	0	0	0
8	July 16-17	1	0	203	0	5	0	0	0	0

Table 4. Catches of juvenile salmon per set (CPUE) in beach seines in the Campbell River estuary, within the Discovery Harbour Marina and in the surrounding nearshore marine area by trip.

Trip No.	Date	No. Sets	Pk	Ch	Estuary Mck	Uck	Mco	Uco	Cut	Sth
1	May 2-3	0	0	0	0	0	0	0	0	0
2	May 6-7	1	0	456	0	968	0	0	0	0
3	May 13-14	3	2	32.3	62.7	250	0	56.7	2.3	1
4	May 21-22	1	0	110	0	693	0	0	0	0
5	June 4-5	0	0	0	0	0	0	0	0	0
6	June 17-18	2	1.5	0	0	45.5	3	61.5	2.5	0
7	July 2-3	2	0	0	0	15.5	5	50	5	0
8	July 16-17	0	0	0	0	0	0	0	0	0

Trip No.	Date	No. Sets	Pk	Ch	Inside marina Mck	Uck	Mco	Uco	Cut	Sth
1	May 2-3	6	10.2	2.2	0	0	0	0	0	0
2	May 6-7	5	10.4	0.2	66.0	934	0	0	0	0
3	May 13-14	6	0.2	1.5	9.8	126.5	0	0.5	0	0
4	May 21-22	6	0.2	1	3.5	28.5	0	0	0	0
5	June 4-5	6	0.3	10.3	3.5	37	0.2	27.2	0	0
6	June 17-18	6	4.3	43.5	1.5	15.2	0	3	0	0
7	July 2-3	6	0	16.7	0.7	3.2	0	0.8	0	0
8	July 16-17	6	0	1.7	0	2.8	0	0.2	0	0

Trip No.	Date	No. Sets	Pk	Ch	Outside marina Mck	Uck	Mco	Uco	Cut	Sth
1	May 2-3	6	583.3	81.3	0	0	0	0	0	0
2	May 6-7	4	1879.8	541.8	5	252.5	0	0	0	0
3	May 13-14	4	2057.8	505.3	12	99.8	0	1	0	0
4	May 21-22	6	478.0	136.0	1	26.8	0	0.3	0	0
5	June 4-5	6	0.2	11.8	8.5	34.8	0.5	3	0	0
6	June 17-18	6	24.7	30.2	20.3	82.8	0	16.7	0	0
7	July 2-3	6	60.7	0	1	5	0	0.2	0	0
8	July 16-17	6	0	13.7	1.5	15.5	0	0.5	0	0

Table 5. Length and weight measurements for juvenile chinook captured in 1996 (Inside=inside marina, Outside=outside marina, Estuary=Campbell River estuary, BS=beach seine, PS=purse seine).

Trip No.	Date	Location	Gear	No. fish	Len. (mm) Range	Len. (mm) X±1SE	Wt (g) Range	Wt (g) X±1SE
3	May 13-14	Inside	BS	30	70-105	92.0± 1.3	3.5-12.4	7.9±0.3
3	May 13-14	Outside	BS	25	75-101	94.5± 1.0	4.3-10.8	8.9±0.3
4	May 21-22	Inside	BS+PS	40	87-109	98.7± 0.8	6.6-12.8	9.8±0.3
"	"	Inside	BS	20	87-106	96.9± 1.1	6.6-12.7	9.3±0.4
"	"	Inside	PS	20	94-109	100.5± 1.0	6.7-12.8	10.0±0.6
4	May 21-22	Outside	BS	31	75-114	98.8±16.7	4.4-16.4	10.4±0.5
5	June 4-5	Inside	BS+PS	48	47-118	92.9± 2.7	0.8-19.4	8.9±0.6
"	"	Inside	BS	33	47-118	86.7± 3.4	0.8-19.4	7.6±0.8
"	"	Inside	PS	15	98-113	106.6± 1.1	8.9-14.2	11.9±0.4
5	June 4-5	Outside	BS+PS	58	77-120	101.2± 1.3	4.7-19.3	11.2±0.4
"	"	Outside	BS	30	77-120	99.9± 1.9	4.7-19.3	11.0±0.7
"	"	Outside	PS	28	84-120	102.7± 1.7	6.2-16.2	11.4±0.6
6	June 17-18	Inside	BS+PS	48	77-133	113.1± 1.7	4.1-30.6	16.4±0.8
"	"	Inside	BS	27	77-131	108.3± 2.2	4.1-25.9	14.3±1.0
"	"	Inside	PS	2	101-133	119.2± 2.1	9.7-30.6	19.8±1.3
6	June 17-18	Outside	BS	29	63-125	92.5± 3.5	2.0-22.9	8.8±1.1
6	June 17-18	Estuary	BS	14	48- 64	54.3± 1.2	-	-
7	July 2-3	Inside	BS+PS	24	72-136	108.8± 4.4	4.2-30.0	15.7±1.6
"	"	Inside	BS	18	72-130	104.1± 4.6	4.2-24.6	13.8±1.7
"	"	Inside	PS	6	75-136	116.2± 9.1	4.3-27.6	18.8±3.5
7	July 2-3	Outside	BS	13	80-162	105.3± 7.2	5.3-53.1	15.7±3.9
"	"	Estuary	PS+BS	26	52- 75	69.8± 2.7	-	-
"	"	Estuary	BS	16	52- 75	60.2± 1.4	-	-
"	"	Estuary	PS	10	76-104	85.1± 2.5	-	-
8	July 16-17	Inside	BS+PS	24	60-147	107.3±5.3	2.0-38.5	16.1±2.1
"	"	Inside	BS	16	60-143	99.2±6.7	2.0-32.4	12.9±2.5
"	"	Inside	PS	8	107-147	123.4±5.0	13.6-38.5	22.5±3.1
8	July 16-17	Outside	BS+PS	41	67-161	97.7±3.4	3.5-53.2	12.3 ±1.6
"	"	Outside	BS	40	67-161	97.7±3.4	3.5-53.2	11.9±1.6
"	"	Outside	PS	1	132	-	28.4	-
8	July 16-17	Estuary	PS	4	74- 84	77.8±2.3	-	-

Table 6. K factors by site for juvenile chinook captured during the 1996 marina study (OM=outside marina, IM=inside marina, BS=beach seine, PS=purse seine, LW=number of chinook measured).

Site No.	Zone	# Times Sampled	Gear Type	Chinook Total	Chinook LW	K Factors Range	K Factors Mean±1SE
1	OM	7	BS	1072	86	0.76-1.34	1.06±0.01
2	OM	8	BS	1539	65	0.80-1.19	1.03±0.01
3	IM	8	BS	5803	50	0.71-1.25	1.03±0.02
4	IM	8	BS	148	39	0.88-1.20	1.02±0.01
5	IM	8	BS	442	55	0.90-1.27	1.04±0.01
6	OM	7	BS	50	16	0.91-1.17	1.08±0.02
7	OM	1	PS	5	1	1.23	1.23
8	OM	1	PS	201	0	-	-
9	OM	2	PS	18	17	0.92-1.28	1.03±0.02
10	OM	1	PS	33	11	0.92-1.12	1.03±0.01
11	IM	7	PS	97	35	0.92-1.24	1.06±0.02
12	IM	2	PS	1652	0	-	-
13	IM	7	PS	118	35	0.93-1.30	1.08±0.02

Table 7. Mean value ± 1SE of K factors for all the chinook measured from all sites except the estuary.

No. of chinook	Zone	Sites	Mean ± 1SE
196	Outside marina	1, 2, 6, 7, 8, 9, 10	1.05 ± 0.01
214	Inside marina	3, 4, 5, 11, 12, 13	1.04 ± 0.01
410	Inside and outside marina	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	1.04 ± 0.00

Table 8. Comparison of catch per unit effort (CPUE) of juvenile salmonids at sites 2 and 6, in 1996, and site 21 during 1982-86 (Chin = chinook).

1982-86 Site 21							1996 Site 2							1996 Site 6						
Date	# set	Chin	Coho	Chum	Pink	All	Date	# set	Chin	Coho	Chum	Pink	All	Date	# set	Chin	Coho	Chum	Pink	All
May 1-13	16	0.6	0.1	41.4	57.5	100.6	May 2-7	4	257.5	0	391.0	1800.8	2449.3	May 2-7	4	0	0	272.5	954.0	1226.5
May 16-30	16	23.9	28.7	96.4	6.8	155.8	May 21-22	2	42.0	0	408.0	1434.0	1884.0	May 21-22	2	0	0	0	0	0
June 4-10	12	100.3	17.6	67.2	11.6	196.6	June 4-5	2	5.0	0	0	0	5.0	June 4-5	2	22.5	0	7.5	0.5	30.5
June 16-26	20	63.8	8.1	218.5	11.0	301.3	June 17-18	2	12.5	0	90.0	17.5	107.5	June 17-18	2	2.0	0	0.5	0.5	3.0
June 28-July 10	18	42.7	1.2	125.3	147.1	316.2	July 2-3	2	1.0	0	1.0	0	2.0	July 2-3	2	0.5	0	3.5	0	4.0
July 16-23	16	43.3	0.2	9.6	0.2	53.3	July 16-17	2	33.0	0.5	32.0	0	55.5	July 16-17	2	1.0	0.5	0	0	1.5

Table 9. Results of single factor analysis of variance for lengths and weights of juvenile chinook captured, by gear and zone of capture (BS = beach seine, PS = purse seine; Estuary = Campbell River estuary, Inside = Inside Discovery Harbour Marina, Outside = Outside Discovery Harbour Marina).

Date 1996	Gear	Zone	Factor	N	Avg.	F	P Value
May 13-14	BS	Inside	Length	30	92.0	2.4294	0.1250
	BS	Outside	"	25	94.5		
May 13-14	BS	Inside	Weight	30	7.9	5.1676	0.0271
	BS	Outside	"	25	8.9		
May 21-22	BS	Inside	Length	20	96.9	0.7657	0.3858
	BS	Outside	"	31	98.8		
May 21-22	BS	Inside	Weight	20	9.3	2.5465	0.1170
	BS	Outside	"	31	10.4		
May 21-22	BS	Inside	Length	20	96.9	5.6509	0.0226
	PS	Inside	"	20	100.5		
May 21-22	BS	Inside	Weight	20	9.3	5.4672	0.0247
	PS	Inside	"	20	10.4		
June 4-5	BS	Inside	Length	33	86.7	10.6383	0.0018
	BS	Outside	"	30	99.9		
June 4-5	BS	Inside	Weight	33	7.6	10.3328	0.0021
	BS	Outside	"	30	11.0		
June 4-5	BS	Inside	Length	33	86.7	14.7003	0.0004
	PS	Inside	"	15	106.6		
June 4-5	BS	Inside	Weight	33	7.6	12.3520	0.0010
	PS	Inside	"	15	11.9		
June 4-5	BS	Outside	Length	30	99.9	1.1875	0.2805
	PS	Outside	"	28	102.7		
June 4-5	BS	Outside	Weight	30	11.0	0.2502	0.6189
	PS	Outside	"	28	11.4		

Table 9 (cont'd).

Date 1996	Gear	Zone	Factor	N	Avg.	F	P Value
June 4-5	PS	Inside	Length	15	106.6	2.5856	0.1155
	PS	Outside	"	28	102.7		
June 4-5	PS	Inside	Weight	15	11.9	0.3450	0.5602
	PS	Outside	"	28	11.4		
June 17-18	BS	Inside	Length	27	108.3	14.2969	0.0004
	BS	Outside	"	29	92.5		
June 17-18	BS	Inside	Weight	27	14.3	12.8060	0.0007
	BS	Outside	"	28	9.0		
June 17-18	BS	Estuary	Length	14	54.3	290.9959	1.11E-19
	BS	Inside	"	27	108.3		
June 17-18	BS	Estuary	Length	14	54.3	56.0998	3.38E-09
	BS	Outside	"	29	92.5		
June 17-18	BS	Inside	Length	27	108.3	12.7372	0.0009
	PS	Inside	"	21	119.2		
June 17-18	BS	Inside	Weight	27	14.3	12.4662	0.0010
	PS	Inside	"	21	19.8		
June 17-18	BS	Outside	Length	29	92.5	36.0198	2.49E-07
	PS	Inside	"	21	119.2		
June 17-18	BS	Outside	Weight	29	9.0	40.4271	7.71E-08
	PS	Inside	"	21	19.8		
July 2-3	BS	Inside	Length	18	104.1	0.0214	0.8847
	BS	Outside	"	13	105.3		
July 2-3	BS	Inside	Weight	18	13.8	0.2255	0.6384
	BS	Outside	"	13	15.7		

Table 9 (cont'd).

Date 1996	Gear	Zone	Factor	N	Avg.	F	P Value
July 2-3	BS	Estuary	Length	16	60.2	46.1477	2.7E-07
	BS	Outside	"	13	105.3		
July 2-3	BS	Estuary	Length	16	60.2	73.5904	8.38E-10
	BS	Inside	"	18	104.1		
July 16-17	BS	Inside	Length	16	99.2	0.0458	0.8313
	BS	Outside	"	40	97.7		
July 16-17	BS	Inside	Weight	16	12.9	0.1032	0.7493
	BS	Outside	"	40	11.9		
July 16-17	BS	Inside	Length	16	99.2	5.6692	0.0263
	PS	Inside	"	8	123.4		
July 16-17	BS	Inside	Weight	16	12.9	5.6692	0.0263
	PS	Inside	"	8	22.5		
All dates	BS	Inside	Length	144	96.8	0.1267	0.7221
	BS	Outside	"	167	97.5		
All dates	BS	Inside	Weight	144	10.5	0.1498	0.6990
	BS	Outside	"	167	10.8		
All dates	PS	Inside	Length	70	111.4	8.0530	0.0055
	PS	Outside	"	29	103.7		
All dates	PS	Inside	Weight	70	15.7	7.0896	0.0091
	PS	Outside	"	29	12.0		

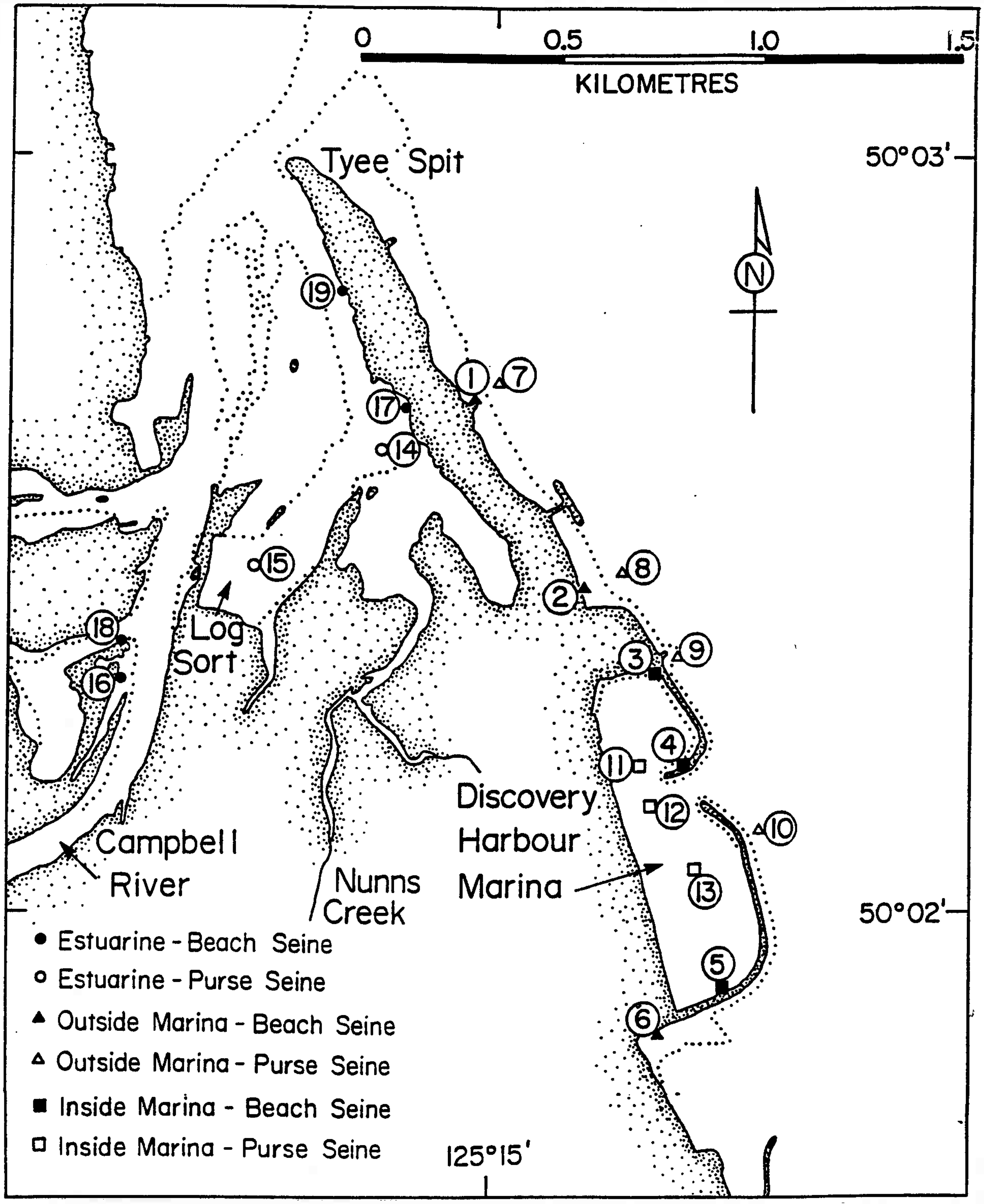
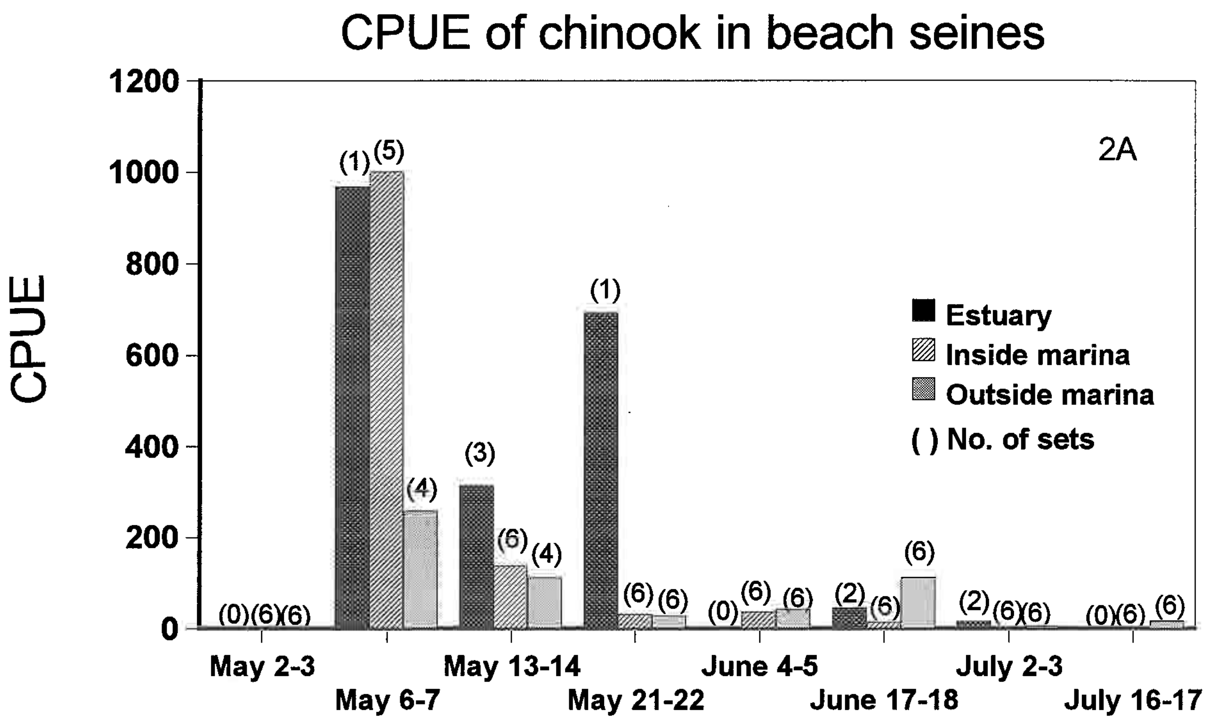


Figure 1. Map of the Campbell River estuary, Discovery Harbour Marina and surrounding nearshore area showing the location of the sites sampled with purse seines and beach seines.



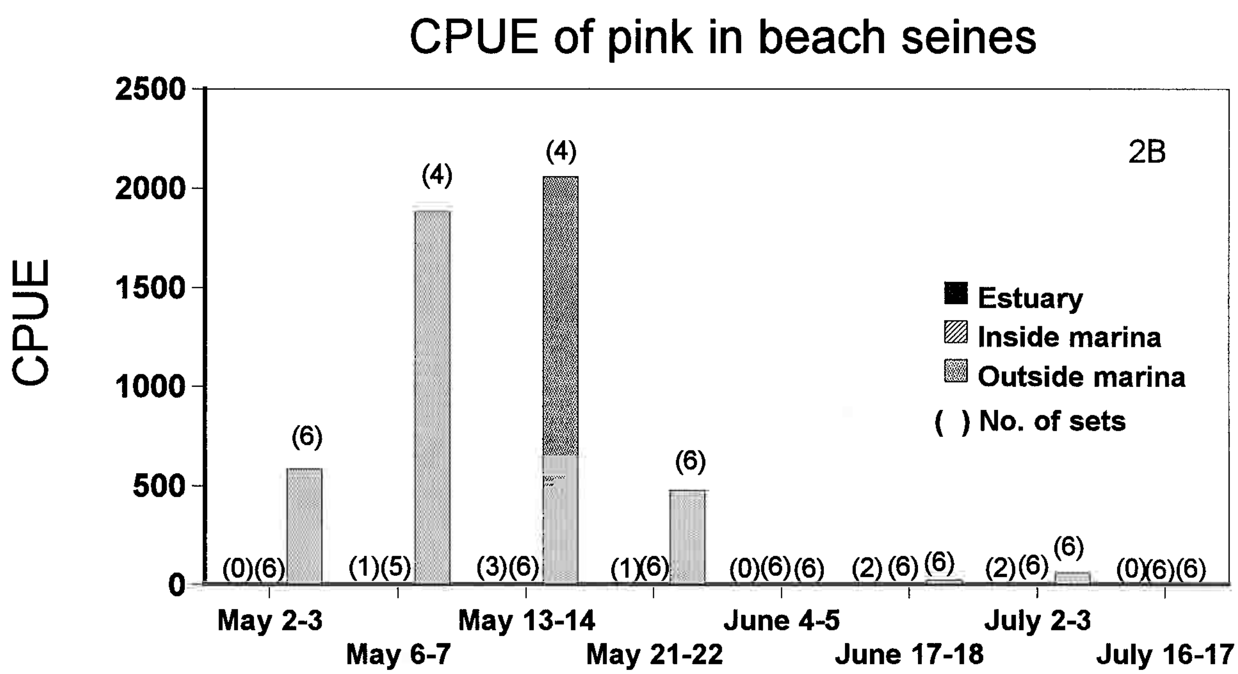


Figure 2A. CPUE of chinook captured in beach seines by zone.
Figure 2B. CPUE of pink captured in beach seines by zone.

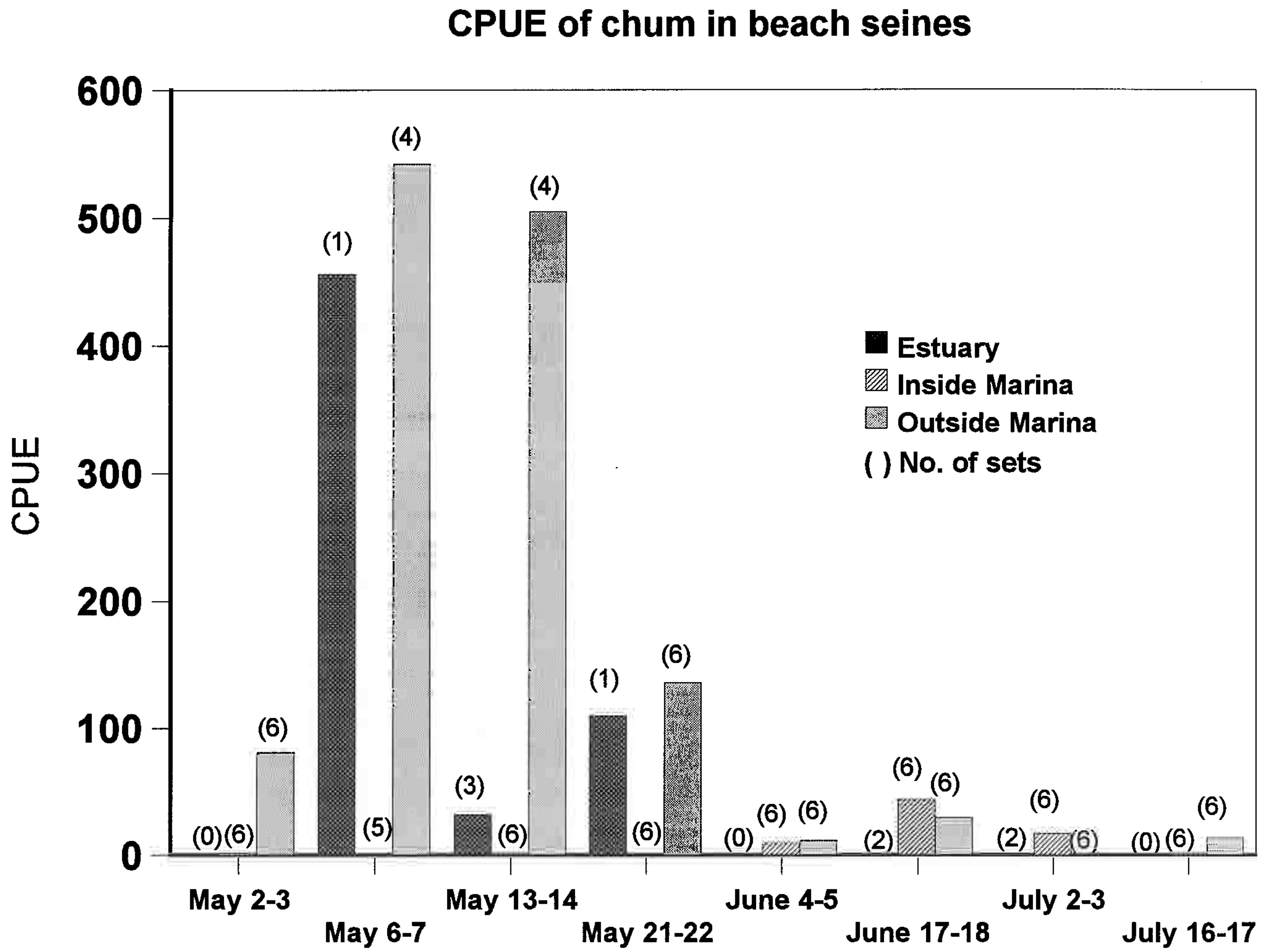


Figure 3. CPUE of chum captured in beach seines by zone.

Figure 4A. Frequency and mean values ± 1SE for length and weight of juvenile chinook captured in beach seines at sites 3, 4, and 5, inside the marina, on May 13-14.

Figure 4B. Frequency and mean values ± 1SE for length and weight of juvenile chinook captured in beach seines at sites 1 and 2, outside the marina, on May 13-14.

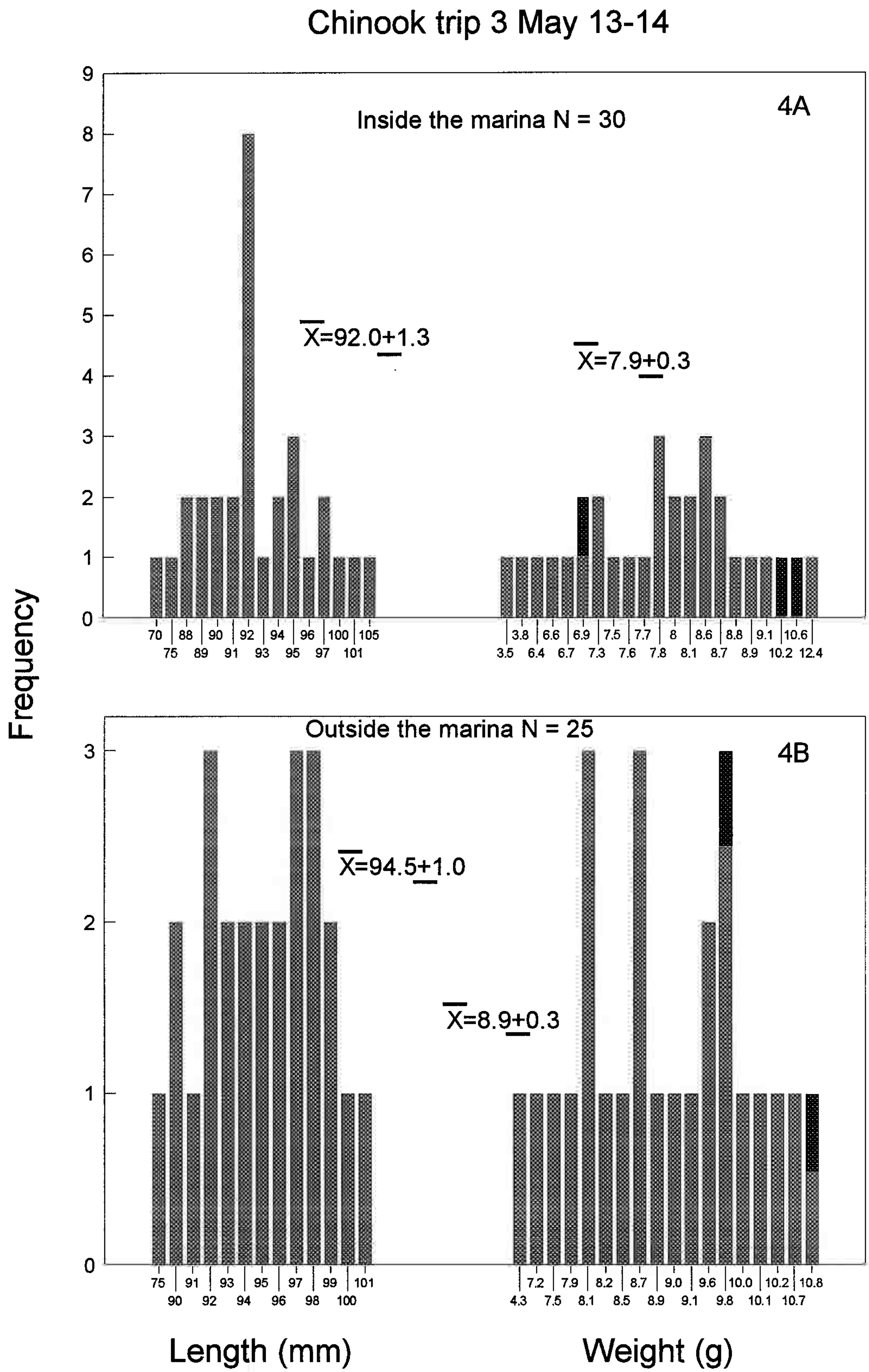

Chinook trip 3 May 13-14
Frequency
Inside the marina N = 30
4A
X=92.0+1.3
X=7.9+0.3
Outside the marina N = 25
4B
X=94.5+1.0
X=8.9+0.3
Length (mm)
Weight (g)

Figure 5A. Frequency and mean values ± 1SE for length and weight of juvenile chinook captured in purse and beach seines at sites 4, 5, 11 and 13, inside the marina, on May 21-22.

Figure 5B. Frequency and mean values ± 1SE for length and weight of juvenile chinook captured in beach seines at sites 1 and 2, outside the marina, on May 21-22.

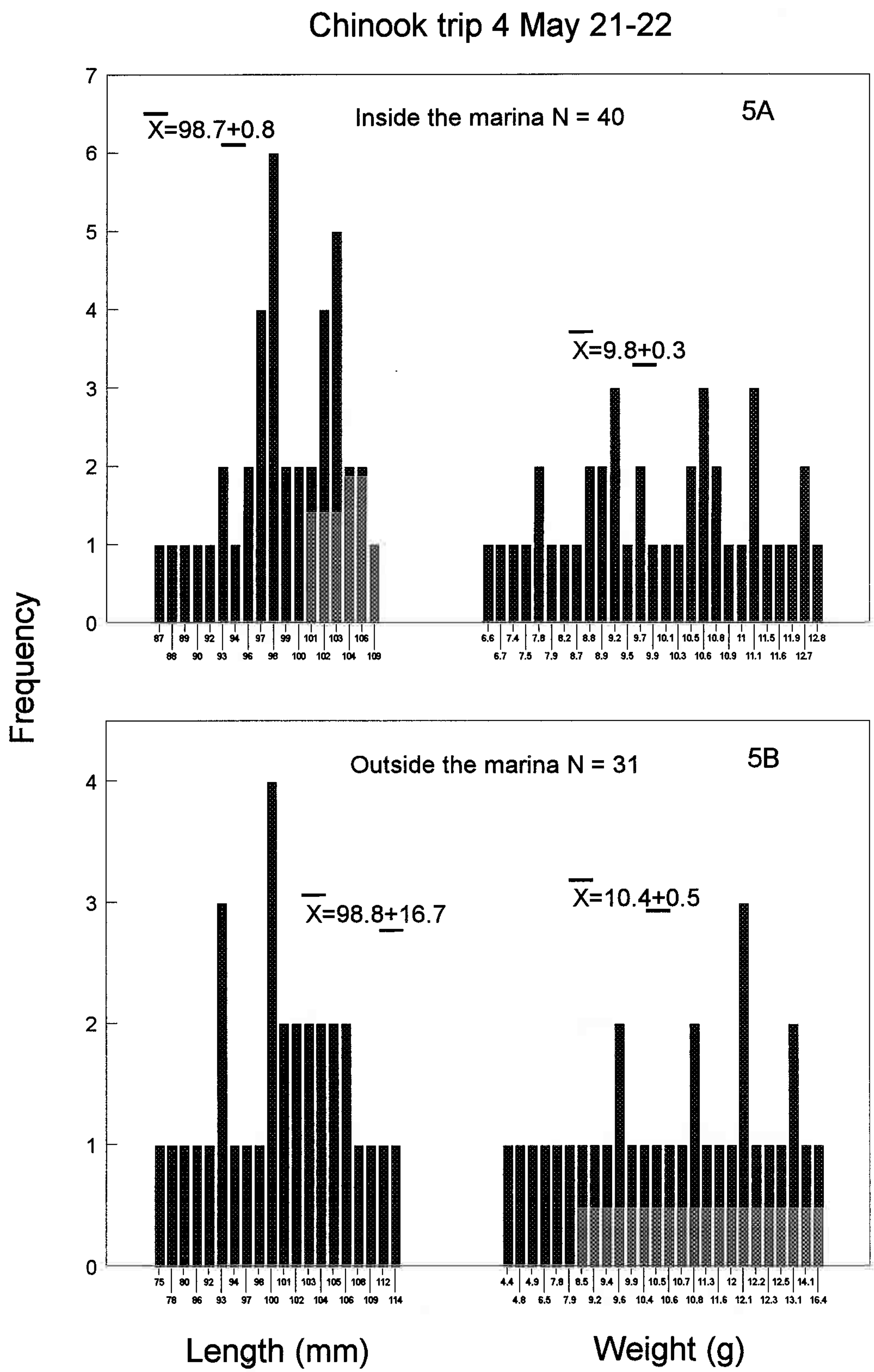

Chinook trip 4 May 21-22
Inside the marina N = 40
5A
X=98.7+0.8
X=9.8+0.3
Outside the marina N = 31
5B
X=98.8+16.7
X=10.4+0.5
Frequency
Length (mm)
Weight (g)

Figure 6A. Frequency and mean values ± 1SE for length and weight of juvenile chinook captured in purse and beach seines at sites 3, 4, 5, 11 and 13, inside the marina, on June 4-5.

Figure 6B. Frequency and mean values ± 1SE for length and weight of juvenile chinook captured in purse and beach seines at sites 1, 2, 6, 9 and 10, outside the marina, on June 4-5.

Chinook trip 5 June 4-5

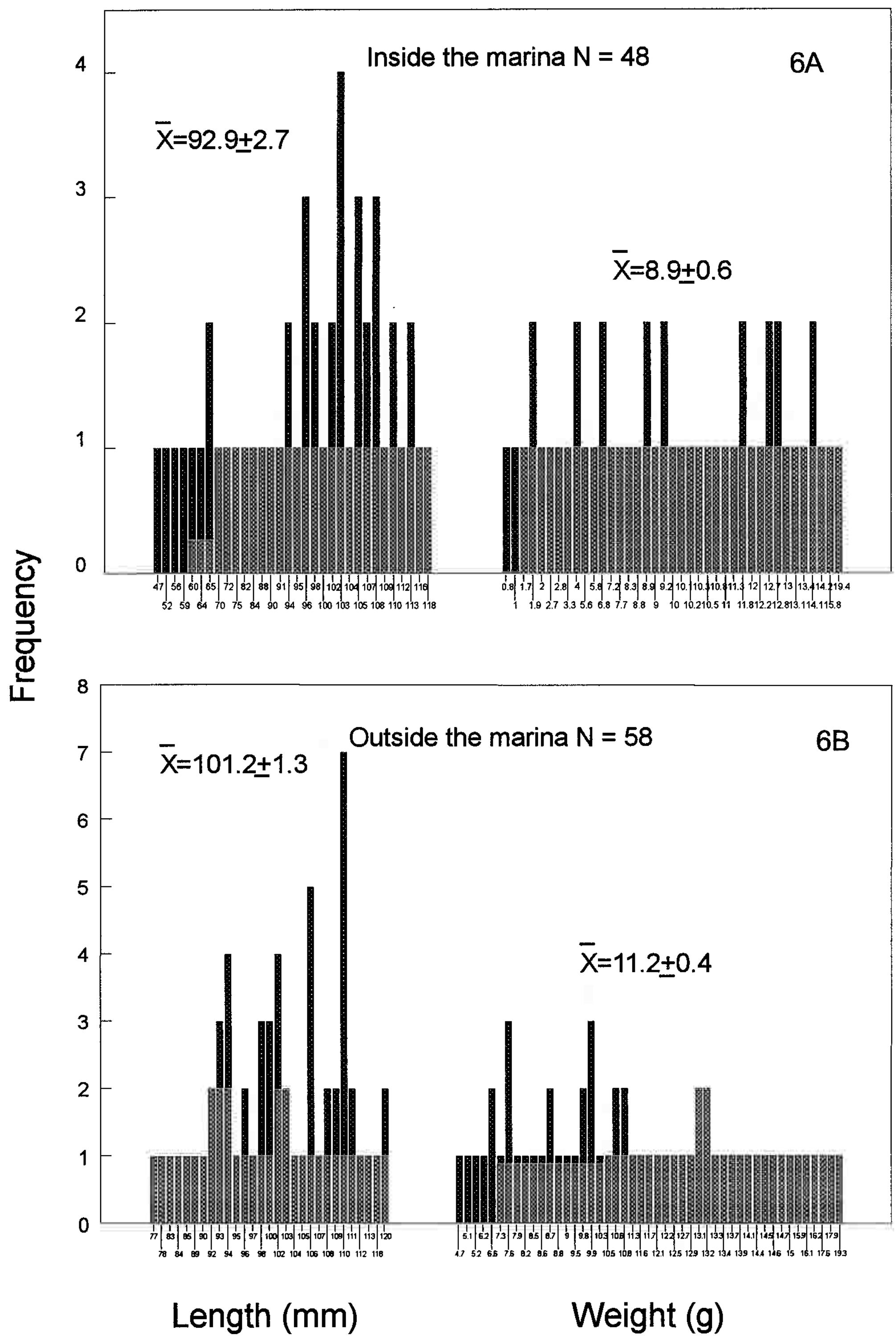


Figure 7A. Frequency and mean values ± 1SE for length and weight of juvenile chinook captured in purse and beach seines at sites 3, 4, 5, 11 and 13, inside the marina, on June 17-18.

Figure 7B. Frequency and mean values ± 1SE for length and weight of juvenile chinook captured in beach seines at sites 1, 2, and 6, outside the marina, on June 17-18.

Chinook trip 6 June 17-18

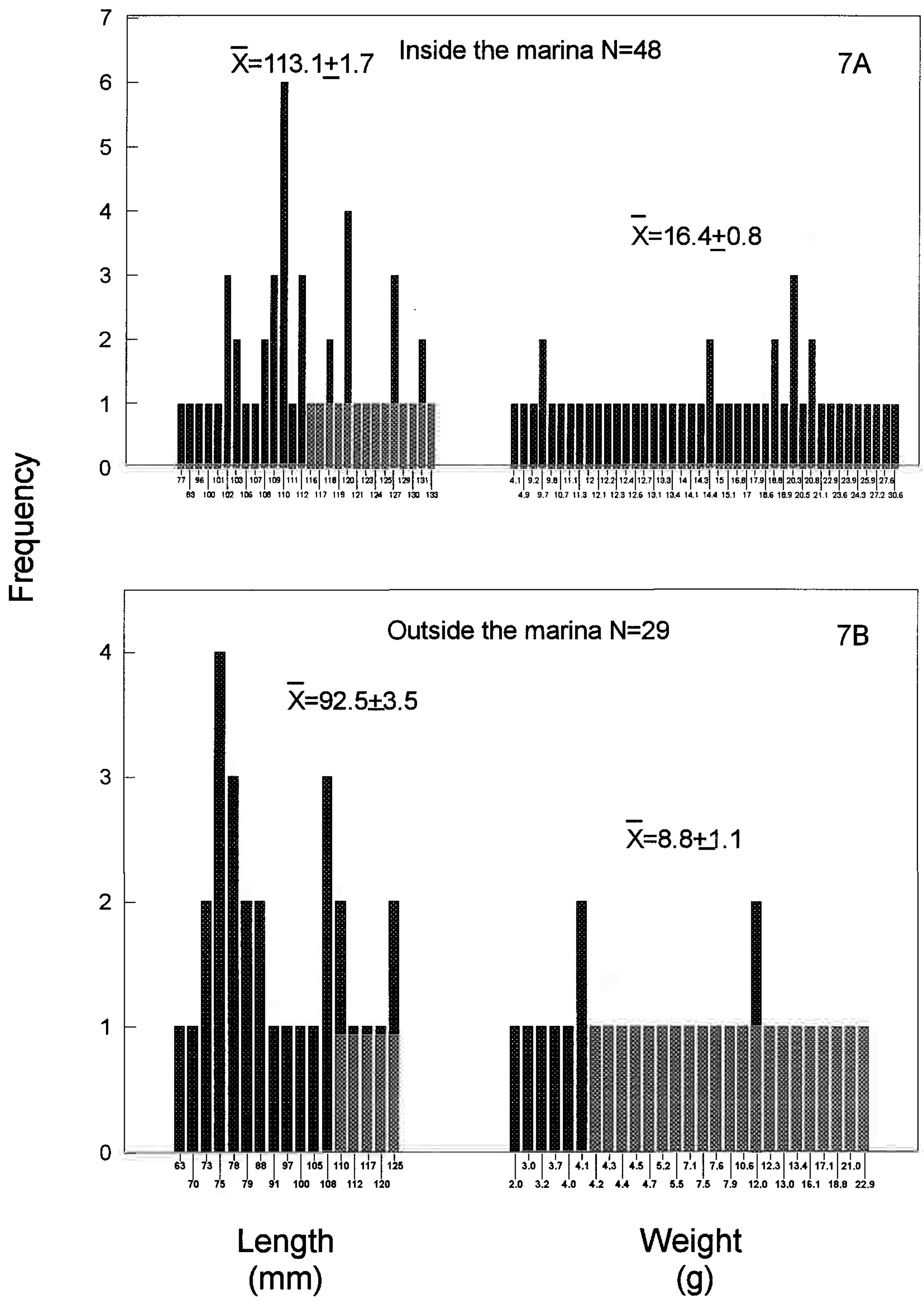


Figure 8A. Frequency and mean values ± 1SE for length and weight of juvenile chinook captured in purse and beach seines at sites 3, 5, 11 and 13, inside the marina, on July 2-3.

Figure 8B. Frequency and mean values ± 1SE for length and weight of juvenile chinook captured in beach seines at sites 1 and 2, outside the marina, on July 2-3.

Chinook trip 7 July 2-3

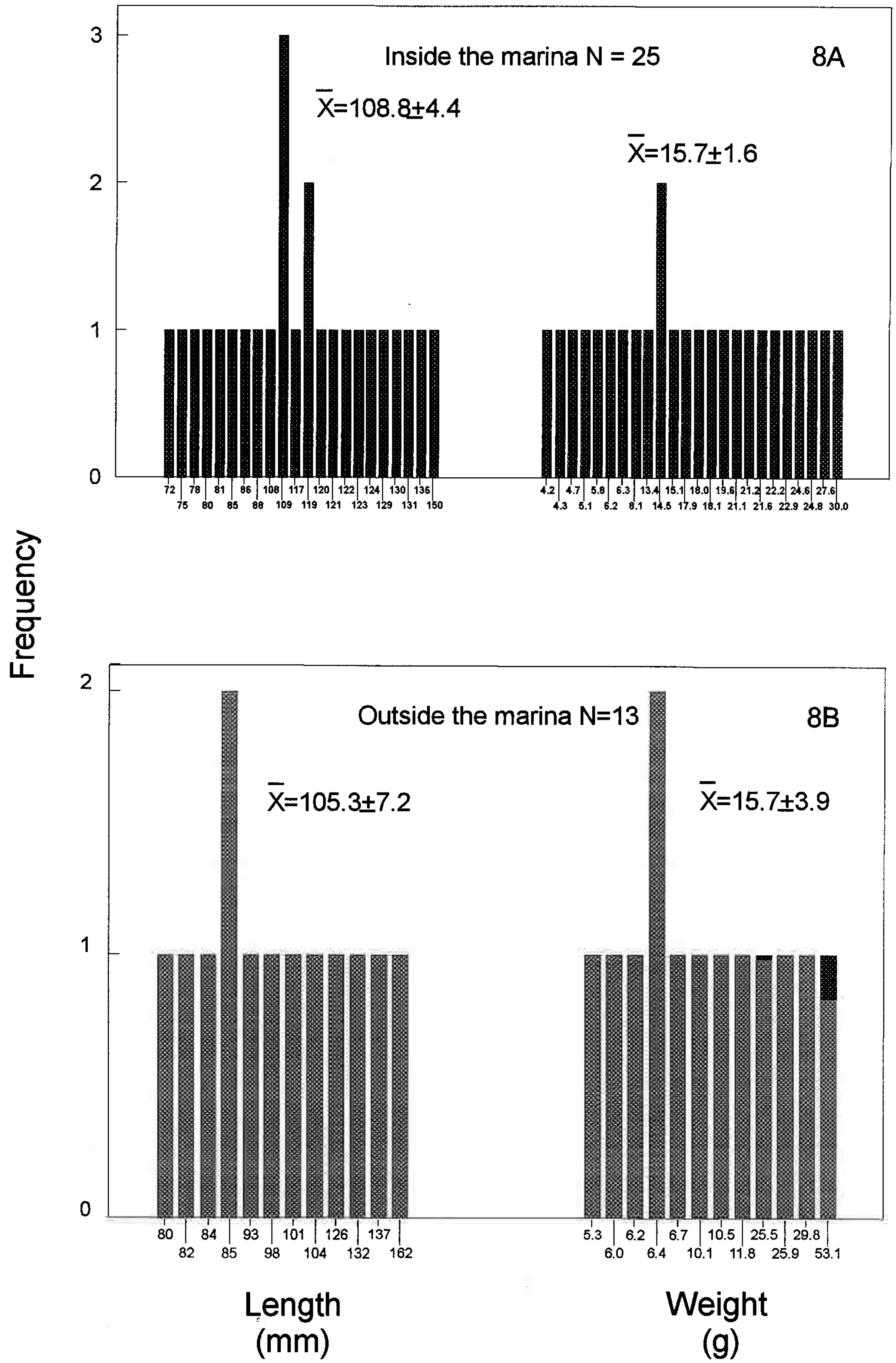


Figure 9A. Frequency and mean values ± 1SE for length and weight of juvenile chinook captured in purse and beach seines at sites 3, 4, 5, 11 and 13, inside the marina, on July 16-17.

Figure 9B. Frequency and mean values ± 1SE for length and weight of juvenile chinook captured in purse and beach seines at sites 1, 2, 6 and 7, outside the marina, on July 16-17.

Chinook trip 8 July 16-17