CHAPTER 11

94320-P Program Planning and Communication

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Prince William Sound Science Center: Project 94320-P

Sound Ecosystem Assessment (SEA) Planning & Communication

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I. Goals of SEA Planning & Communication

As stated in the Detailed Project Description, project 320-P had goals relating first to scientific planning and integration, and second, to communication and community involvement. These goals derive from the need to continue local public and scientific collaboration out of which SEA originally developed.

A. Objectives given in the DPD for scientific planning and integration were to develop conceptual models of key ecosystem processes that link SEA research to other EVOS research, including the areas of apex predators, and benthic and intertidal communities; as well as to provide direction for further SEA projects. These objectives were to be accomplished through:

(1) coordination with other researchers to minimize overlap between different EVOS-sponsored projects as they developed, and;

(2) conceptual modeling and strategic planning to develop, refine and evaluate scientifically testable hypotheses.

B. Objectives for communication and community involvement were to invite the continued input of regional residents in SEA design and implementation. This is to be accomplished through:

(1) preparation and distributions of reports on SEA progress, and;

(2) meeting with residents and other scientists as necessary to promote communication and representation of community input in research.

Note that goals overlap where scientific planning requires clear communications between scientists, the EVOS Restoration Office, the public and SEA.

SEA has developed from extensive internal coordination and in April 1994 (when SEA-94 was initiated) substantial integration already existed among SEA researchers and projects. Project 320-P therefore focused on building connections between SEA and other proposed EVOS-sponsored research where interaction seemed most beneficial. Some attention was also given to working with SEA personnel who were new to the SEA team, and to reviewing SEA integration in the field.

II. Scientific Planning activities

Coordination with other EVOS-sponsored researchers: Project 320-P has been involved in the development or refinement of a number of hypotheses that relate to SEA programs, to the general EVOS restoration effort, or to expressed community concerns. Many of these contributions occurred during EVOS-sponsored workshops or meetings of other researchers; all involve interactions with other scientists. SEA-PLAN personnel attended, and in some cases assisted in organizing, the following meetings to work on the scientific interaction of SEA, other EVOS research, and regional interests:

(1) EVOS Research Priorities workshop (Anchorage, 13-15 April)
(2) "Friends of the Forage Fish" workshop (Anchorage, 9 May)
(3) Nearshore Trophics workshop (Anchorage, 10 May)
(4) July 28 meeting (Cordova) to integrate SEA research with related EVOS projects
(5) Forage Fish workshop for research coordination (Anchorage, 19-20 September).

Interactions during these workshops were positive and productive, although the effect, if any, of SEA-PLAN participation on the refinement of other investigator's existing hypotheses cannot readily be judged. SEA-PLAN typically provided information on SEA organization, hypotheses, field operations or observations, as well as feedback on scientific ideas and concerns expressed by other researchers. For example, the initial choice in May of a focal study area by the forage fish project was influenced by details of SEA research provided by SEA-PLAN during the May 9 workshop. SEA-PLAN also assisted the nearshore trophics group with preparation of their cover document (TCSISS 1995) regarding opportunities for cooperation with SEA.

Development of hypotheses: In some cases, SEA-PLAN participation led directly to the development of research proposals based around refined hypotheses. In particular, SEA-PLAN assisted directly in the formulation or development of projects on nearshore trophic dynamics (95009A-E), the role of humpback and killer whales in the ecosystem (95013, 95014, 95320V) and ecological relationships of birds and forage fish (i.e. tests of the hypothesis that food availability limits recovery of some marine birds. Projects 95022, 95320Y). In every case, proposals developed in this manner were designed to be both non-overlapping and complimentary to SEA program research. Many were highly ranked by the Restoration Office in initial review.

SEA Proposal & budget coordination: In addition to these activities, project 320-P assisted coordination of SEA by working closely with the SEA Chief Scientist to prepare the SEA 1995 proposal cover document and complete the on-time, coordinated submission of the program's 1995 proposal package of 21 integrated brief project descriptions (15 June deadline). This work involved the organization of numerous meetings of the SEA Scientific Committee to make sure proposals were integrated, shared costs where appropriate and, later, were prioritized. Project 320-P also was responsible for tracking the SEA program's cumulative proposed budget and working extensively with both ADF&G and UAF to finalize various versions of this proposal budget, as well as the detailed 1994 and proposed 1995 budgets for SEA projects administered through UAF, particularly the PWS Science Center projects.

III. Communications and community involvement

Public reports on SEA progress: The primary report to the public on SEA activities from project 320-P has been the SEA Activities Bulletin. Two issues (July and September 1994) were produced. The bulletin provides a brief progress report on SEA research. The first issue focused on what the purpose of SEA is, what projects were doing at the start of the field season, and where samples were being collected. The second issue provided details on the rest of the field season and on some early findings of the projects.

In addition to the bulletin, project 320 organized a report to the Cordova community on the 1994 research field season. Public interest in the SEA program has been high, and we received many request for more information about the research and our findings. The report was held in Cordova on September 10th, and provided interested members of the public a chance to meet with the SEA researchers and hear a synopsis of their summer research.

Communications and community input: Project 320-P has been responsible for organizing all meetings and teleconferences of the SEA Scientific Committee during the field season. These generally took place once a month and usually involved contacting researchers in several parts of the state, as well as those in the field in Prince William Sound This project also reported on SEA programs at two meetings of the PWS Fisheries Ecosystem Planning Group (June 1, July 5) and discussed the research program with interested members.

This project also attempted to organize visits of SEA research boats to the village of Chenega. This resulted in the *Orca Challenger* stopping in at Chenega, although scheduling conflicts prevented an extensive visit. The *Alaska Beauty* cancelled an open house visit to Chenega Bay on the advice of the Chenega Corporation, as many community residents were away for work or for the Exxon trials. In addition, 320-P personnel have visited Chenega and Tatitlek during SEA research to talk with interested residents. In response to requests from area residents, project 320-P has facilitated the attendance of residents from other Prince William Sound communities (Chenega Bay, Tatitlek, Valdez) at the October review of the SEA program.

Formal community visits between SEA field programs and the villages of Chenega Bay and Tatitlek less successful than we had hoped, because of two factors. First, Sound residents had a very busy summer, and it was generally difficult to find a suitable date to visit a community. Second, SEA researchers drew up their 1994 budgets prior to plans for community visits. Hence, visits were planned at the expense of time budgeted for research. In the future, the money and time for community visits should be included as such in proposals and budgets, and sufficient lead time should be allowed to carefully schedule the visit with the communities.

CHAPTER 12

Sound Ecosystem Assessment - Synthesis of 1994 Results

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Synthesis of SEA 1994 Preliminary Results

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The SEA program entered the field in late April, 1994, to begin accumulating data for use in formal tests of key conjectures relating the survival of juvenile pink salmon and herring to ecosystem-level processes in Prince William Sound. The twelve individual projects comprising SEA have presented their preliminary results in previous chapters. This concluding section attempts a synthesis of information relative to hypotheses guiding the field and laboratory studies.

Natal Habitat Hypothesis

Work in 1994 in herring natal habitats investigated relationships between spawn density in natal and the kinds and abundance of birds capable of eating spawn. Surfbirds, Bonaparte's, mew and glaucous-winged gulls, and harlequin and sea ducks exhibited strong positive statistical correlation with variables characterizing egg distribution and density. Surfbirds, mew gulls and sea ducks are primarily spring migrants through the region and do not occur in substantial number until late April, during or after most spawning has occurred. The results of 1994 surveys support the hypothesis that bird numbers are positively related to egg abundance, and that consumption (as indicated by total numbers present) is a function of egg density.

Prey/Switching Hypothesis

The adoption of optimal foraging theory to questions about predation losses sustained by 0-age pelagic fishes (to include pink salmon and herring) arose as a result of a first-order carbon budget constructed for Prince William Sound (Figure 1). Given levels of primary production reported for the region (Goering et al, 1973), annual rates of secondary and higher-level productivity were computed for hypothetical apex populations. In this formulation, the forage demand for 0-class salmon was calculated from fry numbers, growth rates (wire-tag program) and literature values for growth efficiency. The forage demand for other 0-class fishes (including herring and pollock) was estimated from the proportions these populations make up for the region (Norcross and Frandsen, in press). Standard ecological transfers were used to compute carbon flow to 1+ and older fishes, and marine birds and mammals. The resulting carbon budget pointed to major links between macrozooplankton and all higher levels. Because 1+ and older fishes and other apex predators presumably also eat 0-age and other small fishes, SEA investigators reasoned that seasonal and interannual differences in macrozooplankton populations could modulate predation on the smallest fishes by presenting more or less alternative prey to piscivores. This prey switching idea was adopted as a major organizing theme for the overall program and later became known as the prey switching hypothesis.

Prerequisites for detecting a recognizable signal in this kind of ecological mechanism include: 1) demonstrating significant interannual and seasonal "noise" in the biomass of critical zooplankton populations; and 2) evidence that plankton can play a substantial role in the nutrition of older fishes, birds and mammals. A macrozooplankton linkage represented by carbon flow from krill (euphausiids) to large fish, birds and mammals is well known. Less is known about the contribution of amphipods, pelagic shrimp, copepods and other smaller pelagic taxa to these diets. SEA entered the field in 1994 to document the numbers and kinds of predators feeding on 0-age fishes (particularly juvenile pink salmon and herring) and their alternative prey as a major goal.

Measurable interannual and seasonal variations in spring-time zooplankton biomass (settled volumes) can be demonstrated for selected locations in Prince William Sound as the result of a systematic plankton watch program conducted by the Prince William Sound Aquaculture Corporation in the region since 1981 (Figure 2). This record documents interannual differences of about a factor of five since the plankton watch was initiated in the early 1980s. Further, this biomass is associated with a predictable, early season macrozooplankton bloom comprised mostly of calanoid copepods (Figure 3). Much of the biomass in this bloom is contributed by large calanoids in the genera *Calanus* and *Neocalanus* (see Chapter 4). The peak in biomass occurs from late April into early May each year after which stage V copepodites begin leaving the surface in June to take up residence in the deep water (>200 m) before reproducing the following spring. The predator/prey program of SEA was designed specifically to identify which species of large fishes consumed juvenile pink salmon and herring, and also whether or not zooplankton played any role in modulating losses age-0 fishes to these predators. Fry released primarily from the WN Hatchery at Esther Island were tracked from late April through late July in an attempt to capture and identify fish predators following the schools of juvenile pink salmon as they moved southward in Knight Island Passager.

In 1994, the most significant fish predator on juvenile salmon was walleye pollock (*Thergra chalcogramma*). This common subarctic species, represented mostly by the successful 1988 year-class, was sampled in dispersed off-shore schools at all locations along the western Sound migratory route used by fry from April through June (see Chapters 2 and 9). Predation on juvenile salmon appeared to be greatest during the first week following the release of fry from net pens (see Chapters 1 and 2). Other species consuming juvenile pink salmon included Pacific herring, adult pink salmon, dolly varden trout, Pacific tomcod, and various sculpins and greenlings.

From late April through late May, the abundance of fish predators was low in the shallow near-shore habitats used by juvenile salmon. However, by early June, a dispersion of off-shore pollock populations (documented by acoustics and net sampling) coincided with increasing numbers of near-shore fishes (including pollock) that could consume juvenile pink salmon. By this time significant numbers of fry were approaching 50-60 mm FL, a size that was rare in predator stomachs (Figure 3). This shift from off-shore to near-shore predator fields occurred with summer warming and at about the same time *Neocalanus* populations were descending from the surface waters to overwintering depths in the region. A major seasonal regime shift is suggested at this time by our observations.

When the stomach contents of pollock and herring are pooled across all cruises - April to July - it becomes apparent that both species are primarily planktivores that occasionally eat fish (Figure 4 and 5). This general result is supported by the stable isotope data as well (see Chapter 5). The predominance of large calanoid copepods during May in pollock stomachs occurred at exactly the time most fry were being released from hatcheries in the region, and approximately at the midpoint of the wild fry outmigration. If adult pollock and herring had been consuming fry in proportion to fry abundance in the water column, an increase in juvenile salmon should have characterized the stomach contents of predators during the fry outmigration period. Instead, numbers of all juvenile fish (including salmon) in pollock stomachs were reduced during May (Figure 6). It seems apparent (but by no means well understood) that the timing, magnitude and duration of the early spring calanoid bloom influences how predators utilize fry (and other species of 0-age fishes), at least during

May.

Preliminary results from the predation study also suggest that survival of juvenile pink salmon probably depends on their ability to grow to sizes exceeding about 50-60 mm FL by the time the *Neocalanus* bloom disappears from the surface waters in early June (see Chapters 1 and 2). The extrapolation of this result to broader regions in Prince William Sound hints that knowledge of the spatial overlap between distributions of adult pollock, herring, juvenile salmon and macrozooplankton during April and May might be useful in predicting salmon run strength one year in advance of the adult return. Our results also explain the historically poor production performance of late released hatchery fry from PWSAC facilities (fish < 50-60 mm FL). Fry entering the coastal waters when the zooplankton bloom is declining and nearshore predators are increasing face a hostile environment where size is probably crucial for survival. An experimental late release in 1994 of approximately 15 million fry reared to 50-60 mm FL should provide the first simplistic test of fry size and time of release in this window of highest risk (see Chapter 7). This information will be sought in the marine survival data associated with the return of adults to the Noerenberg and Koernig hatcheries in 1995.

In the most general sense, the results of preliminary studies of pink salmon fry predators and their relationship to alternative prey hint at evolutionary reasons for the timing of the wild outmigration of juveniles in the region relative to the spawning activities of adult pollock and herring. These generally more dominant species move into the region, sometimes in great abundance, to reproduce and then restore their seasonally depleted energy reserves. Pollock spawn prior to the outmigration of juvenile salmon (late February and March); herring deposit eggs during mid-April. After spawning, both species feed intensively.

It appears that pink salmon may have adapted to this phenology by adopting a spawning time in the fall that brings the juveniles out of natal habitats the following spring during the period of the macrozooplankton bloom (Figure 7). This strategy assures plentiful food for the fry and generally warming temperatures (factors influencing their growth rates), but more importantly takes advantage of the predation "refuge" associated with the coincident macrozooplankton bloom that also serves as food for adult herring, pollock and other predators. In years when the macrozooplankton bloom is extensive (a rare case for the overall Sound), consumption of large calanoids by all fish (large and small) is expected to produce elevated survivals for the smallest fishes over most of the Sound, whereas during years of weak upper layer zooplankton, Sound-wide juvenile fish survival is expected to be reduced. A general trend has been identified for wild pink salmon stocks in the region relative to plankton stocks when the effects of exceptionally warm or cold years are taken into account (Cooney and Willette, 1994). The ramifications for other "small fishes" (forage stocks) in Prince William Sound is obvious. Spring-time upper ocean temperatures will almost certainly modify these relationships.

Lake/River Hypothesis

Close correspondence between the long-term record of zooplankton settled volumes at the AFK hatchery in the southwestern corner of the Sound and the strength of the April-May upwelling index computed for a location south of Hinchinbrook entrance led SEA investigators to speculate that the mechanism influencing plankton standing stock in the spring might be variability in the amount of upper-level flushing during the time *Neocalanus* is resident in the surface layers (April and May). This particular hatchery is the closest one in the Sound to flow attributed to the Alaska Coastal Current. The lake-river hypothesis attempts to explain the observed plankton time-series in relation to wind-accelerated surface flushing. High rates of flushing are thought to diminish south Sound plankton stocks by washout.

An alternative view of how wind energy in April and May might be influencing the distributions of macrozooplankton in the surface waters involves consideration of Ekman transport in the Sound under predominately easterly winds associated with low pressure activity in the Gulf of Alaska. This idea notes that while the coastal flow can be accelerated by wind stress caused by Gulf storms, an upper-layer component of northward transport should also occur in the Sound in response to these same winds. When this happens, macrozooplankton in the Ekman layer will be transported to the northern edge of the Sound where a convergence should develop. Because *Neocalanus* is dependent on the upper layers for food in the spring, the weakly swimming copepodite stages will resist the downwelling and begin accumulating in the northern portion of the region. Consistently higher (except during lake years) settled volumes measured in the northwest corner of the Sound might be explained by this transport mechanism.

A third view suggests that fluctuations by phytoplankton, rather than physical forcing, are manifiesting in the zooplankton distributions observed in time and space. This view holds that differences in timing and species composition of the spring plant bloom could produce similar results (see Chapter 3).

Broad-scale circulation patterns capable of moving plankton populations around the region were intensively studied by acoustic doppler profiling in 1994 (see Chapter 8). There were surprises in these results. Large-scale flow in the main basin can be described as two-layered with opposing velocities. Above 150 m, currents average about 30 cm/s while below this flow, currents (opposing) average only about 5-10 cm/s. One implication is that plankters which change their depth distributions seasonally (the large calanoids) will be transported in different directions depending on where they occur in the water column. A stage V *Neocalanus* descending below 350 m may initially be moved westward and then later, eastward. Once an ocean circulation model is available to SEA, "markers" representing different species and life stages will be inserted in the simulated flow and their trajectories described for various levels of wind and buoyancy forcing to describe relationships between plankton distributions and the currents that move this assemblage horizontally and vertically in the region.

Comparison of zooplankton records from northern and southern locations in the Sound demonstrate differences that are probably related to the extent of overwintering habitat for ontogenetic migrators (like the large calanoids). CTD data from 1994 demonstrates remarkably homogeneous conditions in temperature and salinity below about 350 m. This environmental constancy quite likely defines regions in the water column where plankters can successfully enter and maintain diapause, a reduced metabolic state (see Chapter 4). *Neocalanus*, *Calanus* and *Pseudocalanus* all descended to deep water during late spring and summer in 1994. Because of the bathymetry of the Sound, most of the suitable overwintering habitat is located in the northern and western half of the region. Without any current structure to influence their upper layer distributions, early and late stage copepodites of these three species would hypothetically occur in greatest abundance above the deepest water - the northern and western regions. (Figure 8). This has been the historical observation if the hatchery records can be considered representative of broader, adjacent areas (presently being investigated). The degree to which these populations are then spread to other areas of the Sound must be related to wind and buoyancy-driven currents. It seems apparent from the AFK plankton watch record that the kind of quiescent surface conditions that promote the horizontal spreading of upper layer stocks southward over the Sound are rare; only two such events since 1981.

Finally, the 1994 physical observations documented a period of deep basin water renewal, a process generally thought to occur in mid to late summer (Neibauer, et al., 1994). Since *Neocalanus* populations trapped over the shelf south of Hinchinbrook Entrance are unable to descend below about 200 m, they may remain there until currents sweep them off the shelf further to the west (Cooney, 1986). Strong inflow of dense water originating over the shelf and flowing into the Sound each summer should help to "seed" the region with *Neocalanus* of oceanic origin after local populations have migrated to depth. Clustering of carbon stable isotope measurements for *Neocalanus* in 1994 suggests a mechanism for evaluating the external seeding process in succeeding years (see Chapter 5).

Summary

The 1994 SEA observations, coupled with historical data from the region are beginning to reveal a pelagic ecosystem with far more complexities than originally envisioned. The timing of the phytoplankton bloom can apparently vary by as much as 2-3 weeks, representing temporal noise that seems to extend to zooplankton as well (see Chapter 3). Seasonal ontogenetic migrations to overwintering depths for at least three abundant copepods (*Calanus, Neocalanus and Pseudocalanus*) represent a huge translocation of biomass from the surface to depth during late spring and early summer. The significance of this event is becoming evident in prey/predator relationships influencing spring-time juvenile fish survivals but remains an unknown in terms of the overall ecology of the Sound.

Stomach content and stable isotope data demonstrate that many (if not most) pelagic fishes are planktivores during the spring and summer and only occasionally supplement their diets by eating other fish. The degree of piscivory is apparently associated with the timing, magnitude and duration of macrozooplankton blooms interacting with the growth rates of 0-age fishes. Only dolly varden trout exhibited a strictly picivorous feeding dependency of the pelagic species examined in 1994. This observation emphasizes the role of zooplankton in the Sound and verifies a key insight from the carbon budget that most pelagic consumers are supported in large measure directly by macrozooplankton. Winter-time upper-layer zooplankton populations in the Gulf of Alaska are very low (Cooney, 1987), so it seems conceivable that fish like pollock might switch to feeding on small fishes (perhaps including smaller pollock) during this period (if they feed at all).

The phenology associated with pollock and herring spawning in Prince William Sound brings these adult stocks into the region during the fall and winter. Following their spawning in late winter and early spring, these large fish begin feeding heavily to replenish their energy reserves. This intense foraging period probably begins with the onset of the macrozooplankton bloom in April. When *Neocalanus* populations reach stage V and descend to overwintering depths (in early June) pollock and other pelagics using this resource apparently move to the edge of the system where alternative prey (small fishes of a variety of kinds; and other macrozooplankton) is available. Surviving juvenile fishes that have attained about 50-60 mm FL (particularly pink salmon) are apparently at reduced risk to predation by this time.

Because juvenile herring were not studied in 1994, we have no insight about how "predation sheltering" could effect their earlylife-stages. Herring begin hatching in mid May and emerge as small, weakly swimming larvae completely at the mercy of upper-layer currents. The timing of hatching suggests that the early spring calanoid bloom may not play the role it does for juvenile pink salmon (food and shelter from predation). The literature documents macrozooplankton can eat larval herring, so avoiding this event could be advantageous. The forage resource for larval herring (and most other larval fishes) is comprised of the eggs and nauplii of smaller copepods like *Pseudocalanus*. This numerically dominant species produces eggs as long as food is available - probably most of the summer. The adaptation for herring may be to enter the Sound during the period of strong seasonal warming when growth rates are accelerating (May), thus avoiding the macrozooplankton bloom (potential predators) and keying on the period of *Pseudocalanus* reproduction (Figure 5). The time of hatching also corresponds generally to the transition between strong coastal downwelling and weak summer upwelling. Reduced and variable winds during this time may diminish upper-layer flushing and increase the probability for retaining larval stocks entering the Sound at this time. SEA investigators believe that larval herring advected from the system may not recruit to local spawning populations. Thus a link to the lake-river hypothesis is proposed.

These speculations are presented to demonstrate that we are aware of the complexities involved with herring, particularly that factors other than macrozooplankton sheltering may play a role in determining juvenile survival. Herring program emphasis in 1995 and beyond will focus on the juveniles and the environmental factors thought to set levels of cohort survival to age 3. Overwintering mortalities associated primarily with the physiological condition of juveniles in the fall are hypothesized as establishing subsequent levels of adult recruitment.

At the time this report is being submitted, approximately 80 percent of all data collections have been analyzed (average across all projects). The common SEA data base now includes a portion of this information; more is being supplied as analyses are completed and the observations checked for errors. Much of the information obtained in 1994 is being used this year (1995) to refine the sampling design of some components.

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Pink Salmon and Herring Portion of the Prince William Sound Pelagic Ecosystem

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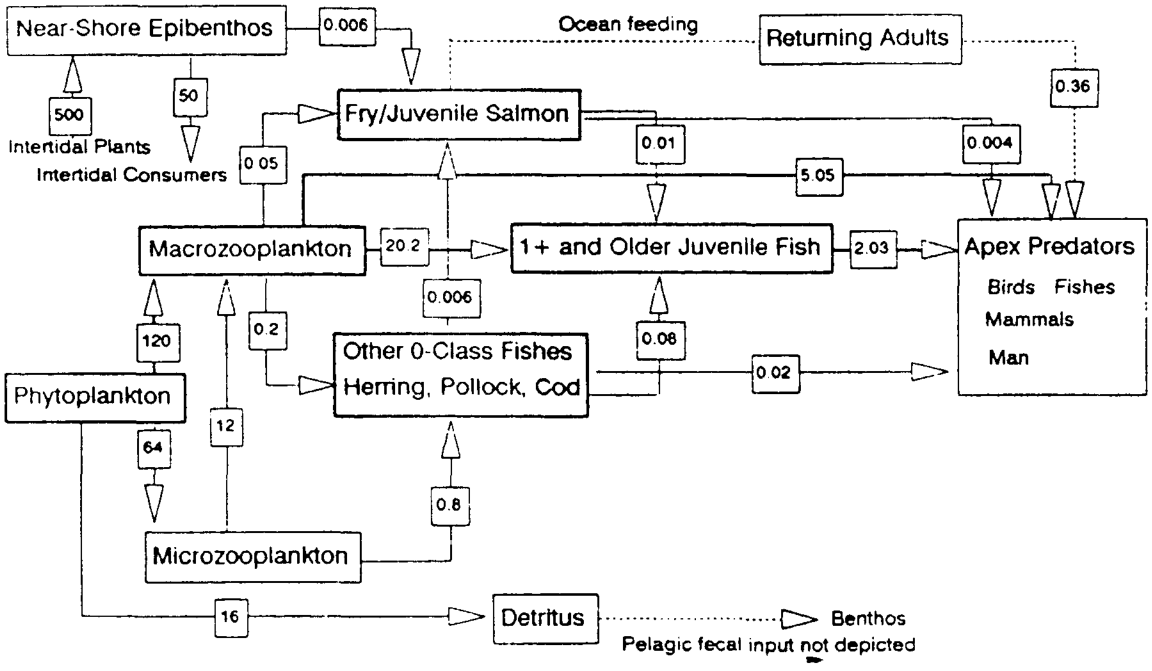


Adapted from Parsons, 1987

Figure 1. An annual carbon budget for the pelagic ecosystem of Prince William Sound.

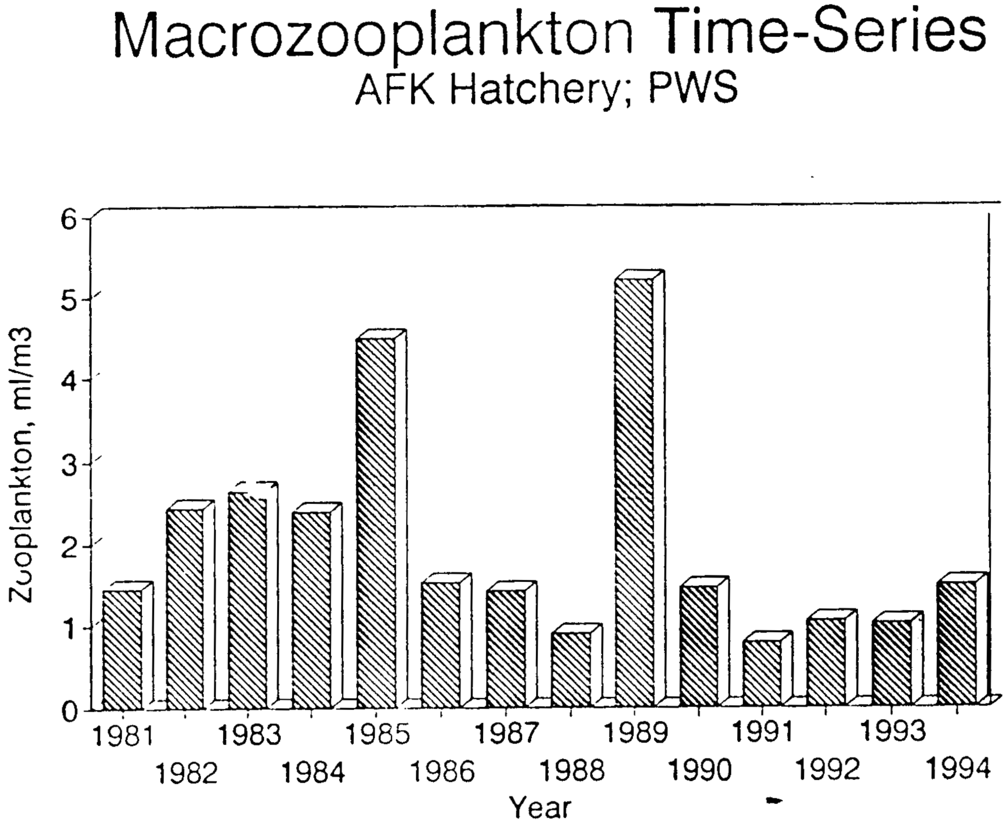


Figure 2. Times-series of average spring-time zooplankton settled volumes from the AFK Hatchery in southwestern Prince William Sound.

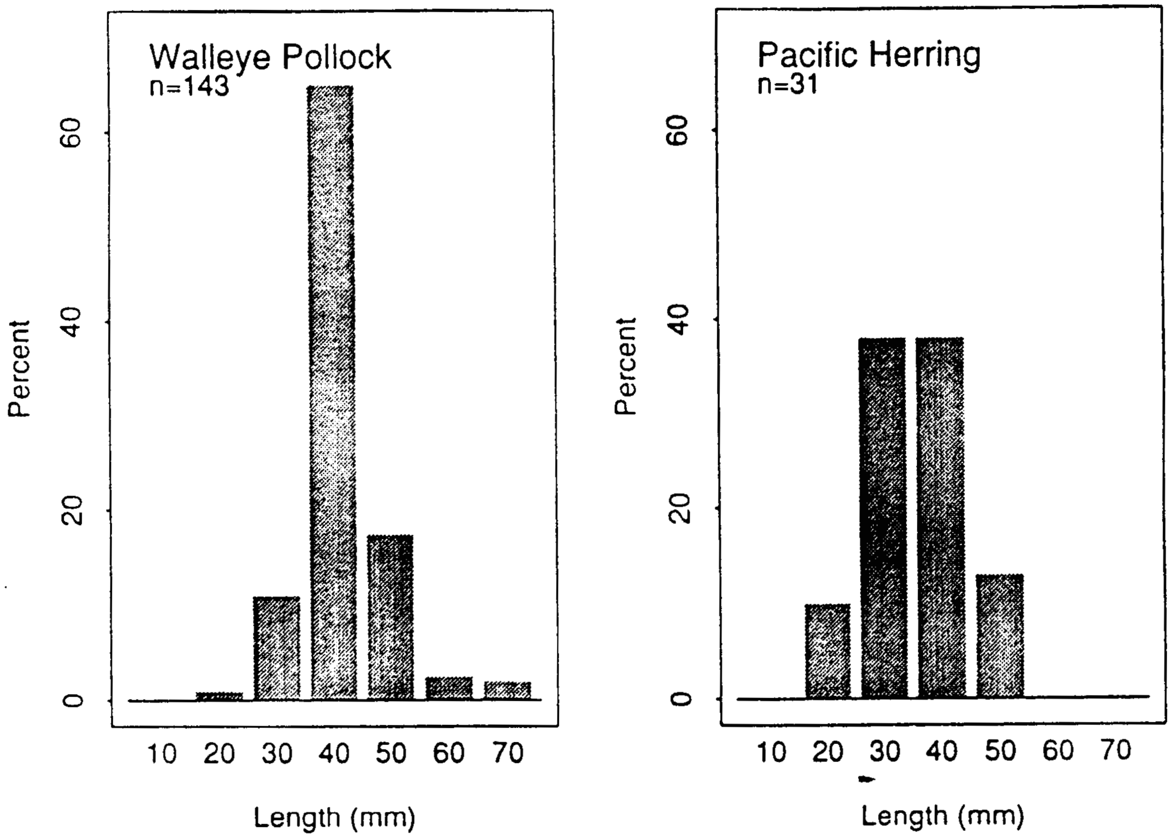


Figure 3. The lengths of pink salmon fry recovered from the stomachs of Walleye pollock and Pacific herring during the spring of 1994 (M. Willette; Chapter 2).

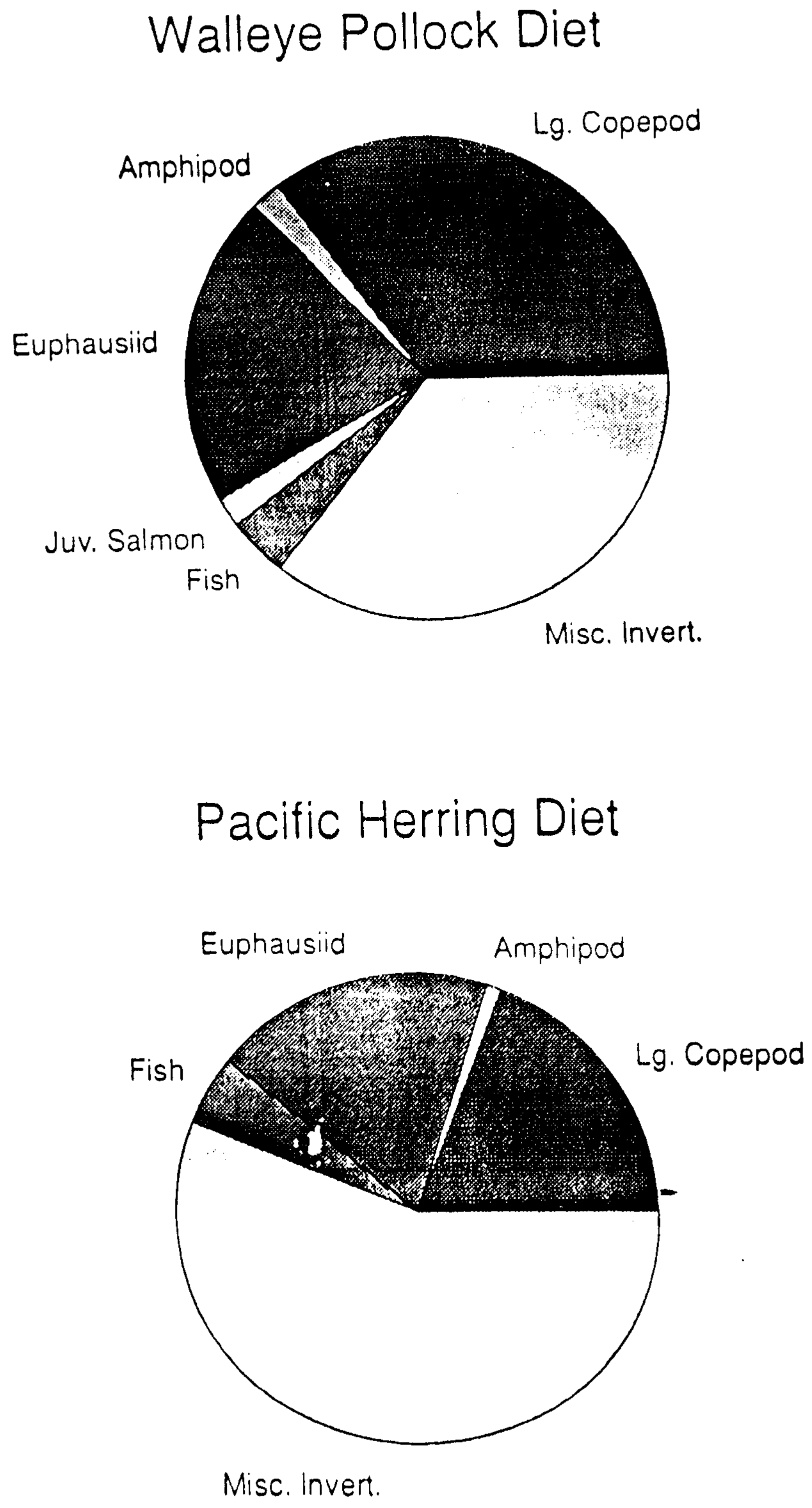
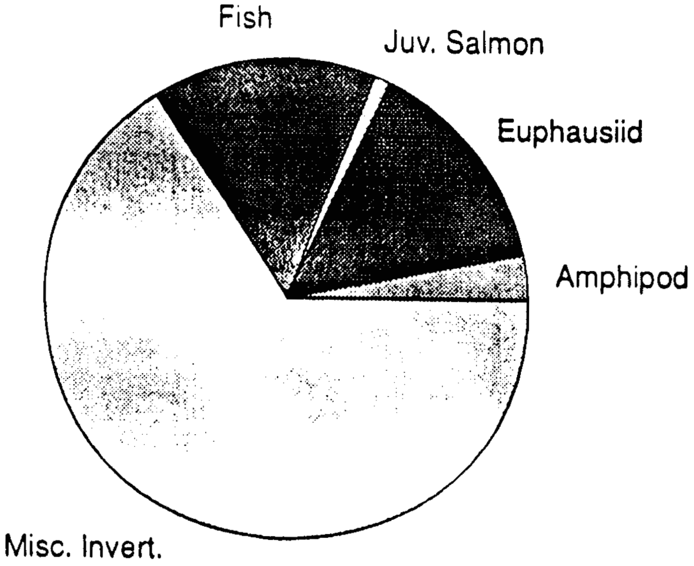


Figure 4. Seasonally averaged stomach contents for Walleye pollock and Pacific herring sampled in Prince William Sound, April - July, 1994 (M. Willette, unpublished).

Adult Pink Salmon Diet



Dolly Varden Trout Diet

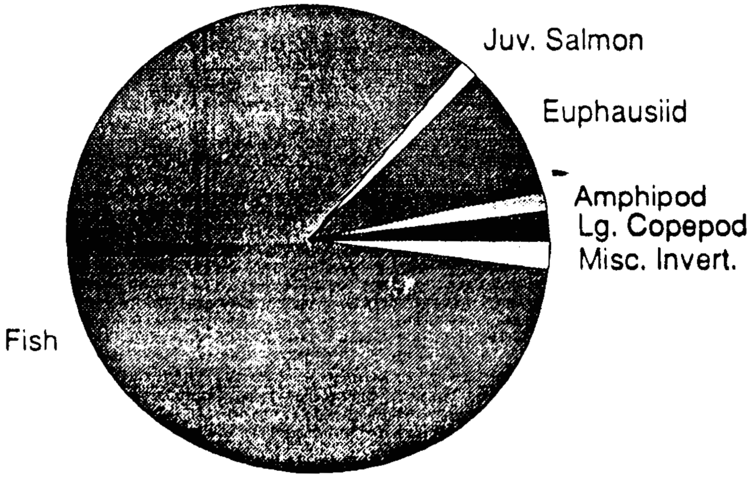


Figure 5. Seasonally averaged stomach contents for adult pink salmon and dolly varden trout sampled in Prince William Sound, April - July, 1994 (M. Willette, unpublished).

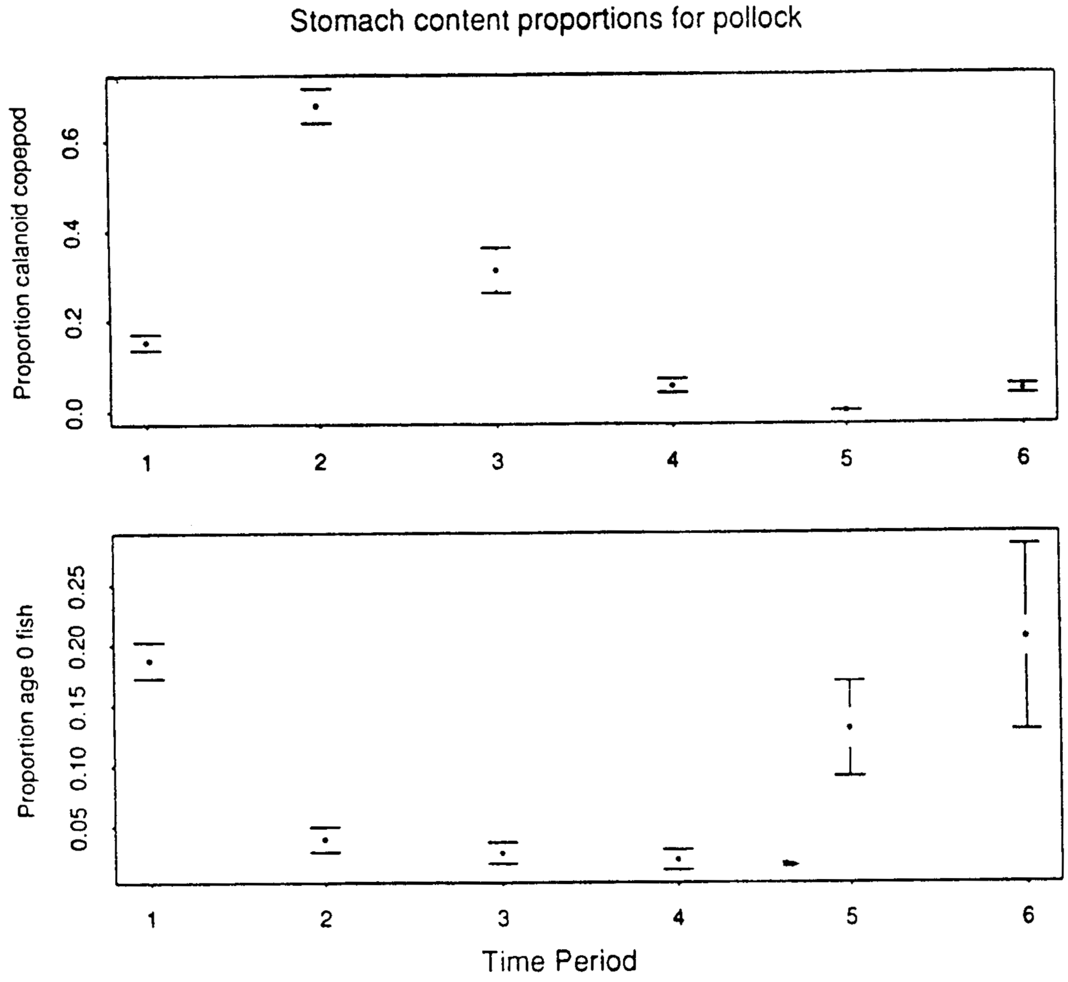


Figure 6. The proportions of calanoid copepods and age-0 fish in the stomachs of Walleye pollock sampled in Prince William Sound, April - July, 1994 (M. Willette; Chapter 2).

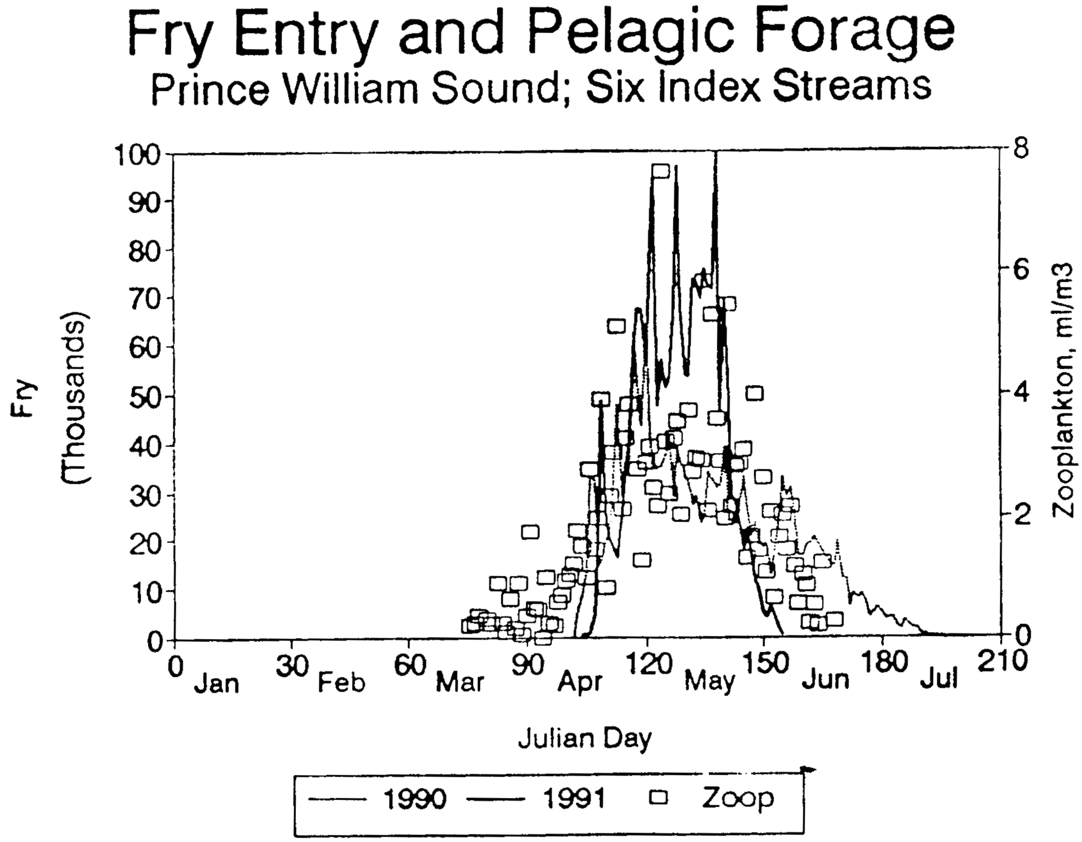
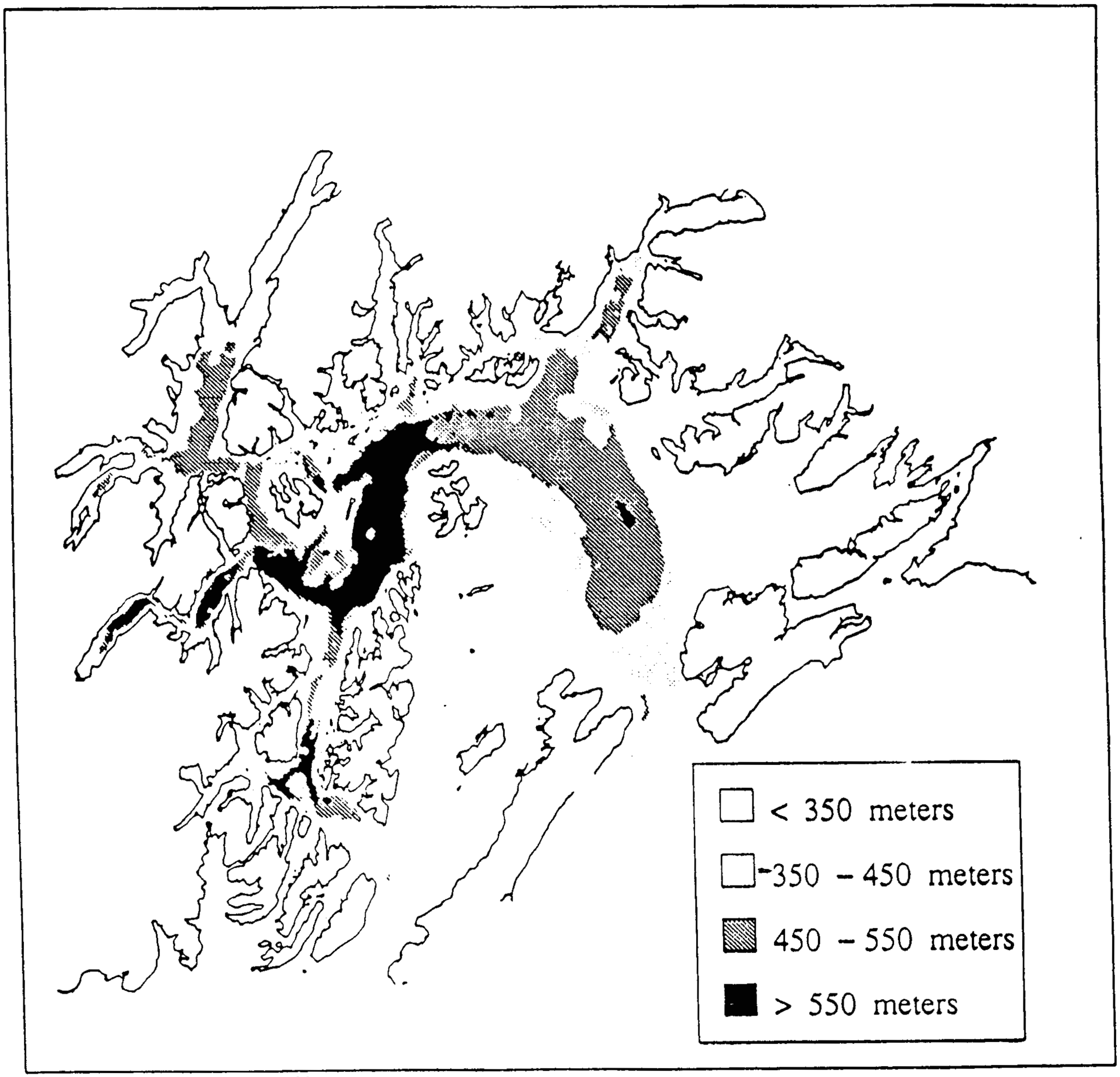


Figure 7. The timing of pink salmon fry entry relative to long-term average zooplankton biomass measured at the AFK Hatchery in Prince William Sound (Cooney, et al., in press).



Scheel and Bentley, PWSSC 1994

Figure 8. Selected bathymetric contours for Prince William Sound illustrating the probable distribution of overwintering habitat for macrozooplankton.