BIOLOGICAL RESEARCH

General

Climate Change and Halibut Biology - Year One Progress Report

by

Steven R. Hare

BACKGROUND

The Climate Change and Halibut Biology project was funded beginning in 1997. The project proposal was included in the 1996 RARA. The design of the program called for a three year study, the purpose of which is to investigate interdecadal changes in growth and recruitment of Pacific halibut and their relationship to North Pacific climate variability. The first year of the project was focused on describing North Pacific climate variability, assembling an ocean bottom properties database and forming working collaborations with other research agencies around the Pacific Rim investigation the influence of climate on marine organisms. This report provides detail on the specific activities and accomplishments achieved in 1997.

DECADAL SCALE CLIMATE VARIABILITY

An extensive analysis of climate records has uncovered a recurring mode of climate variability that fluctuates on an interdecadal time scale. Termed the "Pacific Decadal Oscillation" (PDO, Mantua et al. 1997), it has a spatial pattern similar to the El Niño Southern Oscillation (ENSO), but a much different temporal pattern (Figure 1). During the 20th century, the PDO has alternated between warm and cool phases every 20-30 years. The ENSO tends to appear every 3-5 years with episodes lasting 12-18 months. The PDO also tends to have a stronger North Pacific physical impact than ENSO whose effects tend to diminish with latitude.

The PDO has attracted much recent attention as the possible climate force behind many of the ecosystem changes observed in the North Pacific since the mid 1970s. The transition from one phase of the PDO to another is termed a regime shift. A very strong regime shift occurred in the winter of 1976-77, following regime shifts earlier this century in 1924-25 and 1946-47. Concurrent with the mid 1970s regime shift were dramatic changes in the growth and recruitment of Pacific halibut. Compared to the 20 year period prior to the regime shift, halibut growth slowed while recruitment for many consecutive year classes was very strong. Another regime shift may have transpired in the 1990s (discussed below), but insufficient time has passed to allow complete evaluation of the physical and biological evidence.

Two other papers were produced during research on climate and fisheries within this project. Francis and Hare (1997) presents a detailed view on how climatic processes affect Pacific salmon productivity. Francis et al. (in press) presents a theoretical model of climate-driven bottom-up control of ecosystem productivity.

AN OCEAN BOTTOM PROPERTIES DATABASE

An environmental database has been constructed for the Alaskan continental shelf and upper slope. The purpose of collecting this data is to help understand and explain the observed changes in halibut biology. Virtually all climate analyses focus on variability at the ocean-atmosphere interface. The relevance of ocean surface climate change to halibut depends on the similarity of surface and bottom (where halibut reside) water property trends. Given our knowledge of physical oceanography, it is unlikely that surface indices are adequate proxies for bottom processes. However, while there exists a long-term (1854-present), high quality database of surface observations (COADS, Woodruff et al. 1987), no compilation of conditions at the ocean's bottom has been achieved until now.

Data for this ocean properties database were assembled from several sources, including the National Oceanic Data Center, NMFS, Japanese Meteorological Agency, U.S. Foreign Observer Program, University of Alaska, and IPHC longline surveys. The data were quality controlled through comparison of means and variances in areas of overlap. All data were plotted and depths were checked against an independent bathymetry database (TerrainBase). At present, the database contains 107,000 records and has the following boundary conditions:

Areal coverage: Alaska, British Columbia, and U.S. West Coast (to 30° N) shelf and upper slope.

Depth: Observations must be within 15 m of the bottom and are restricted to areas with a bottom depth of 1000 m or less.

Variables: Temperature, salinity, dissolved oxygen, nutrients (phosphate, nitrate, nitrite)

Time: As complete an historical record as possible

To illustrate the temporal and spatial distribution of data, plots of temperature (Figure 2) and salinity (Figure 3) were made for each decade. Most of the data were compiled in the months May through September. For the study of halibut, this is encouraging since these are the months during which most growth takes place. The amount of usable data varies substantially by decade and variable. The temperature data is the most promising and it is anticipated that annual indices of ocean bottom temperatures by IPHC area from 1960-present can be constructed. For salinity, we may not be able to do better than 5-year averages. The long-term average fields for the months May to September and the years 1961-95 are shown in Figure 4. These average fields should be viewed as the conditions to which halibut have adapted over time. Sustained departures from these average conditions are then prime candidates for exploration as agents of change in halibut biology.

Initial analyses of the database are encouraging and a couple of the early results are included here. To check on the effect, if any, of the 1976-77 regime shift, comparisons were made between five year averages for the periods before and after the winter of 1976-77 (Figure 5). Bottom temperatures increased over the entire shelf west of Kodiak by as much as 2 °C. In the Bering Sea, this is a dramatic jump particularly in the central shelf where long-term ambient bottom temperatures are 2-3 °C. Salinity, on the other hand, showed very little response to the regime shift. This conservative property of salinity indicates that the warming of the bottom waters, particularly in the Bering Sea, was more likely a radiative, rather than an advective, process.

A similar comparison was made between the five year periods surrounding the winter of 1989-90. An increasing number of reports suggest that a climate shift, different in nature than the 1976-77 event, occurred in 1989-90. The PDO index does show a change in character beginning in 1990 – rather than being strongly positive or negative as has been its history, it has hovered around the zero mark for the last several years. Ocean bottom temperatures in the Bering Sea cooled by as much as 3 °C in the five years after 1990 (Figure 6). This cooling trend is unlike changes that occurred at the surface where the heating trend that began in the mid 70's has continued unabated. Partly in response to a sequence of ENSO events in the 1990s, surface waters of the Northeast Pacific warmed by 1-2 °C while surface waters of the Bering Sea showed no significant change.

WORKING COLLABORATIONS

One of the intentions of this project was to "piggyback" other research agencies and groups investigating the influence of climate on marine resources. To that end, several collaborations were initiated this year.

One of the largest investigations of this sort is that currently being led by UW Prof. Ed Miles, termed "An Integrated Assessment of the Dynamics of Climate Variability, Impacts, and Policy Response Strategies for the Pacific Northwest". This 3-year NOAA-funded project is being run jointly by the UW's School of Marine Affairs and the Joint Institute for the Study of the Atmosphere and Oceans. The IPHC is now actively participating in weekly meetings and strategy sessions.

Within the PICES organization there is an initiative termed the CCCC (Climate Change and Carrying Capacity) program. This year, IPHC joined the REX (regional experiment) sub-task team charged with organizing regional comparative experiments to study climate and fish. A set of recommendations and directives were developed at PICES' 1997 Annual Meeting in Pusan, South Korea. Those recommendations will be published shortly in the PICES press.

By May of this year, it had become obvious that a major ENSO event had begun in the equatorial-Pacific. Subsequently, the highly-valued Bristol Bay sockeye salmon had its poorest return year since the mid-1970s. These two events spurred formation of a research group, headed by IPHC staff, that began meeting every three weeks to discuss general issues related to climate and fisheries. The first investigation was the possibility of a climatic regime shift transpiring in the winters of 1989-90 or 1994-5. At this stage, no firm conclusions have been drawn and data collection and analysis continues.

The IPHC joined a NOAA team in writing a grant proposal to rescue non-digitized hydrographic data from institutions around the Pacific Rim. This project is officially titled: Rescue, construction and access of a hydrographic database for the North Pacific and Bering Sea. This project calls for the rescue of historical water column properties data and the construction of a water properties database that will be accessible from the world wide web. The project has strong cross line office cooperation within NOAA (Pacific Marine Environmental Lab (PMEL) and Alaska Fisheries Science Center (AFSC)). It is envisioned that a coupled program between IPHC, PMEL and AFSC will draw upon the talents and resources of both oceanographers and fisheries scientists resulting in a database that provides access to data in a format that has practical utility for both research disciplines. This database will result in an expansion of the ocean properties database described above. The Principal Investigator on this project is Anne Hollowed (AFSC). Co-PIs are Steven Hare (IPHC), Bern Megrey (AFSC), Phyllis Stabeno (PMEL) and James Schumacher (PMEL).

The World Wide Web is fast becoming an interactive communication medium. This project has used the WWW to concentrate and disseminate data, papers, and assorted information on decadal scale climate variability and fisheries. The three main web sites that have been developed are located at:

http://www.iphc.washington.edu/PAGES/IPHC/Staff/hare/html/decadal/decadal.html
http://www.iphc.washington.edu/PAGES/IPHC/Staff/hare/html/1997ENSO/1997ENSO.html
http://www.iphc.washington.edu/PAGES/IPHC/Staff/hare/html/decadal/1995/1995_regime_shift.html

The first site contains contents and links to meetings, institutions, people, manuscripts and references dealing with decadal scale climate variability. The second site concentrates on the 1997-8 ENSO event and the third site concentrates information on the possible 1995 regime shift. All three sites are maintained on a regular basis, receive considerable outside contributions and all receive a large number of daily "hits.".

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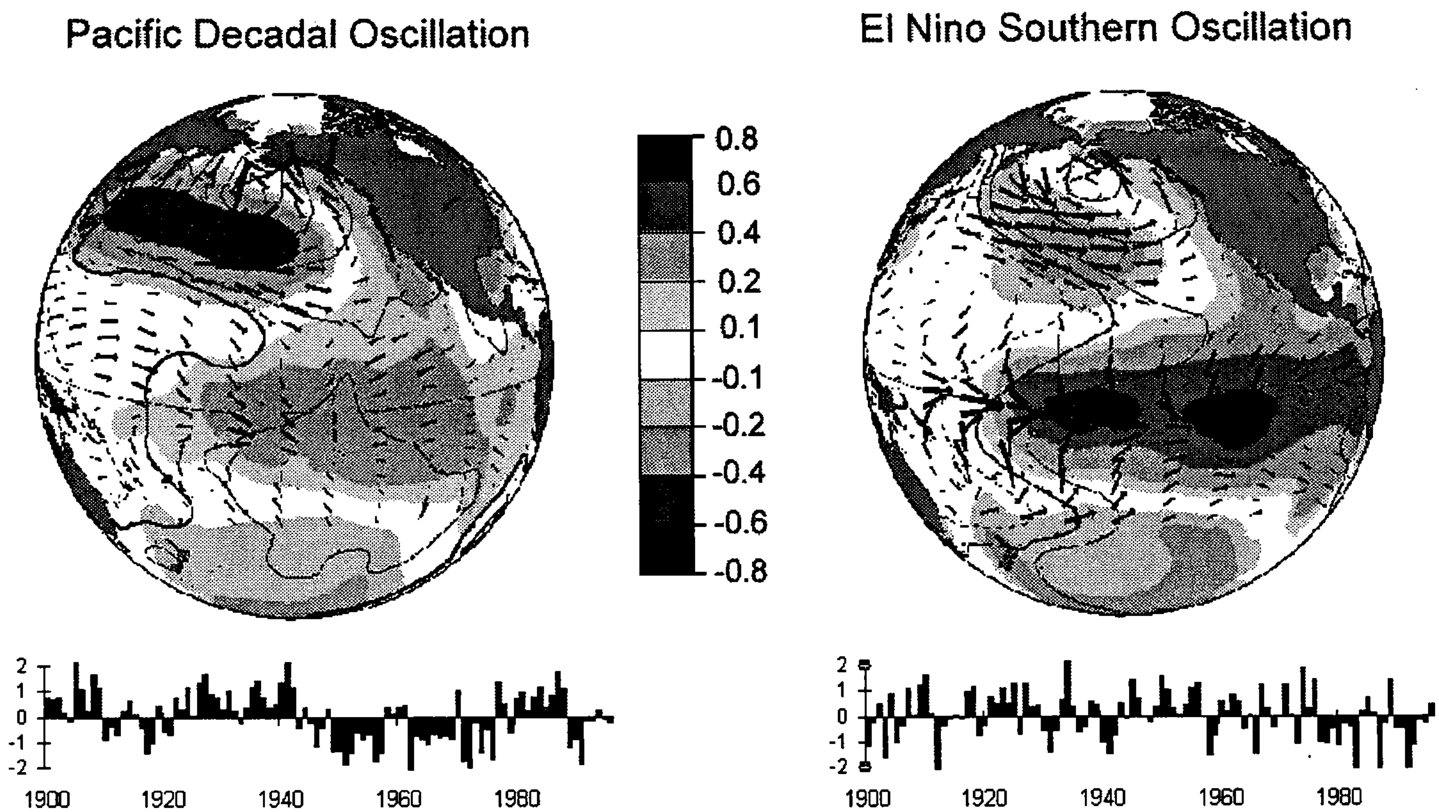
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El Nino Southern Oscillation
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0.6
0.4
0.2
0.1
-0.1
-0.2
-0.4
-0.6
-0.8
2
1
0
-1
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1900
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1900
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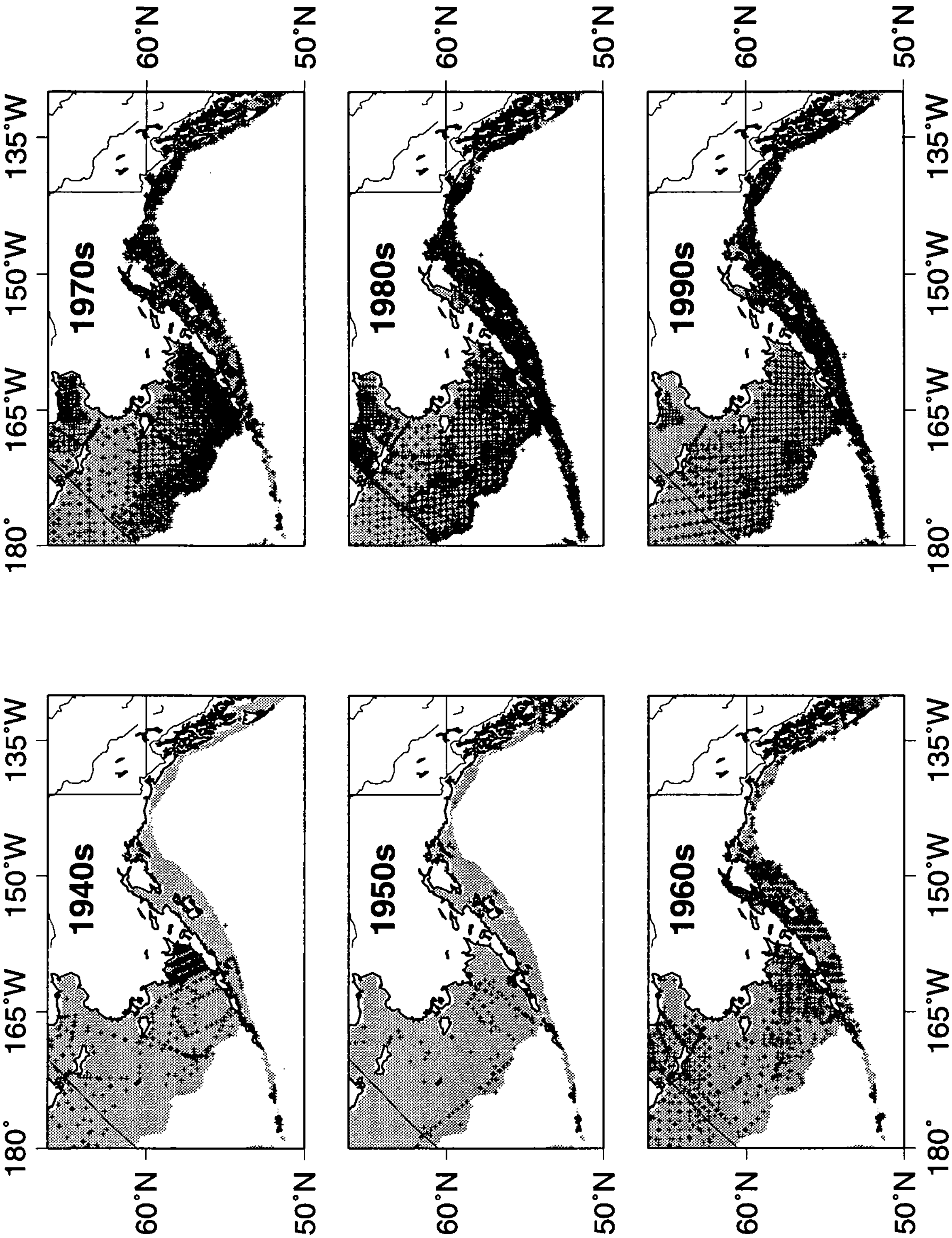
1960
1980

Figure 1.


1940s
1950s
1960s
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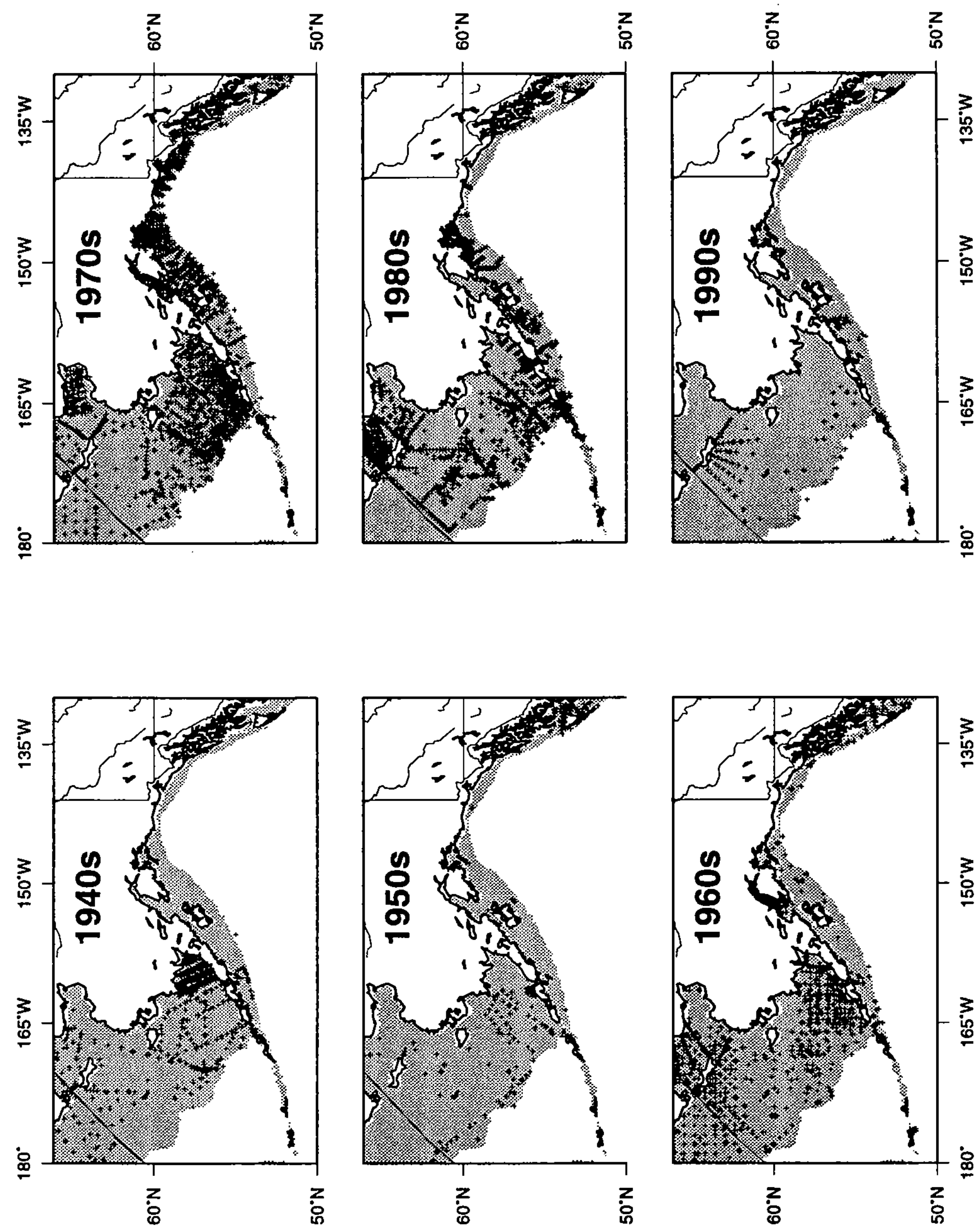
1980s
1990s
180°
165°W
150°W
135°W
60°N
50°N

Figure 2.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180°
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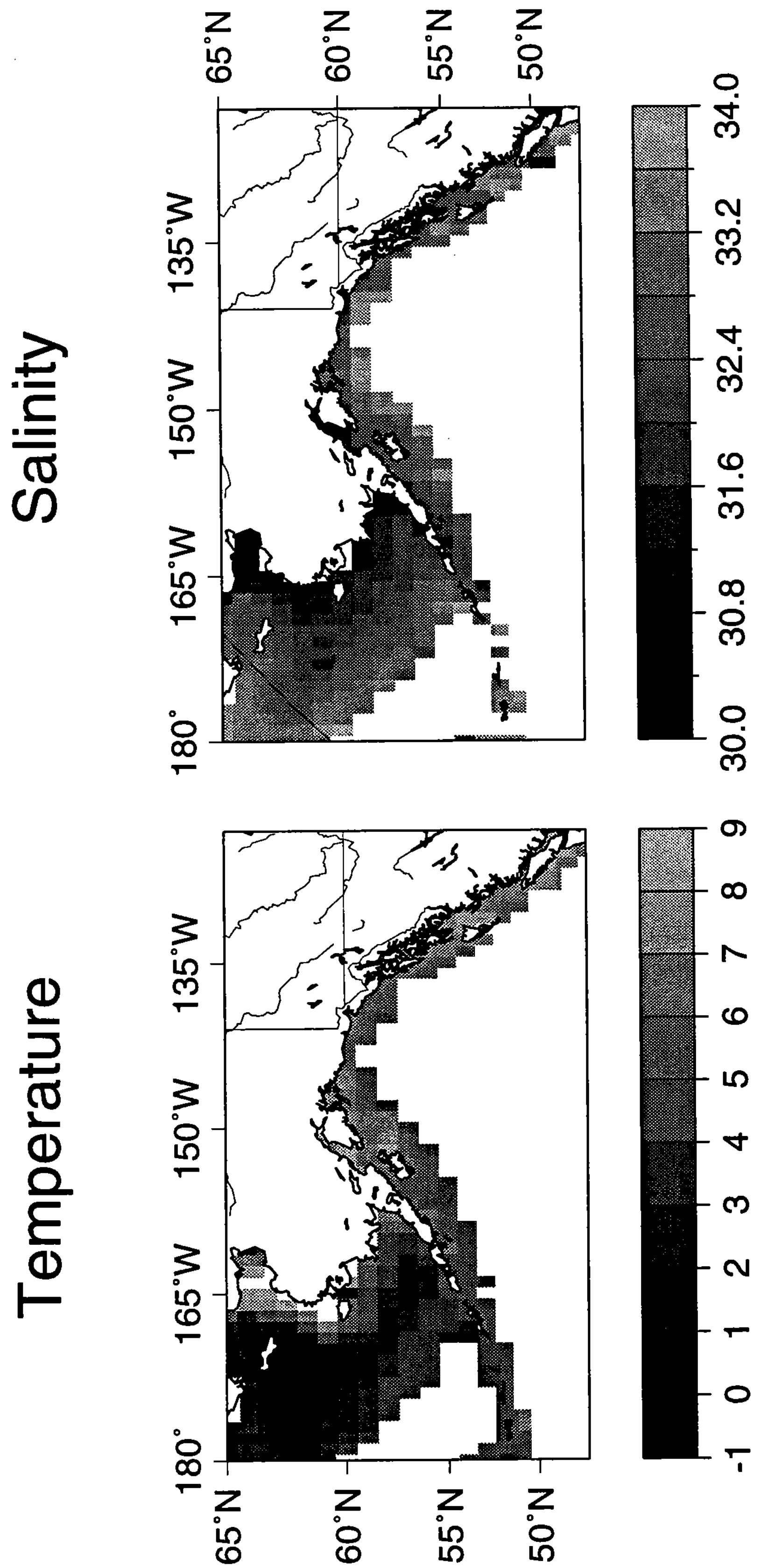
Figure 3.


Salinity
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60°N
55°N
50°N
180°
165°W
150°W
135°W
30.0
30.8
31.6
32.4
33.2
34.0
Temperature
65°N
60°N
55°N
50°N
180°
165°W
150°W
135°W
-1
0
1
2
3
4
5
6
7
8
9

Figure 4.

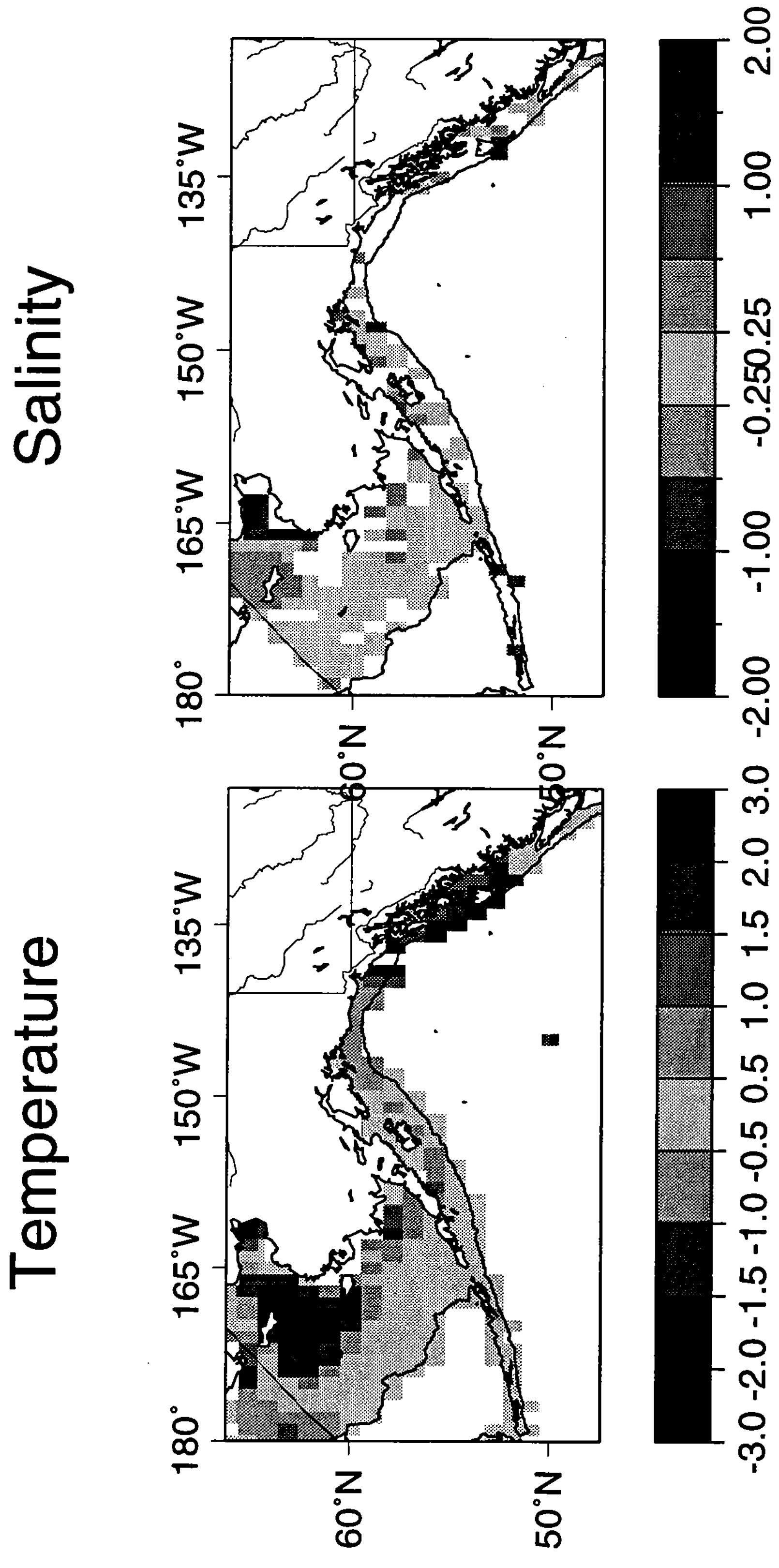
Temperature
Salinity
180°
165°W
150°W
135°W
60°N
50°N
-3.0 -2.0 -1.5 -1.0 -0.5 0.5 1.0 1.5 2.0 3.0
-2.00
-1.00
-0.25
0.25
1.00
2.00

Figure 5.

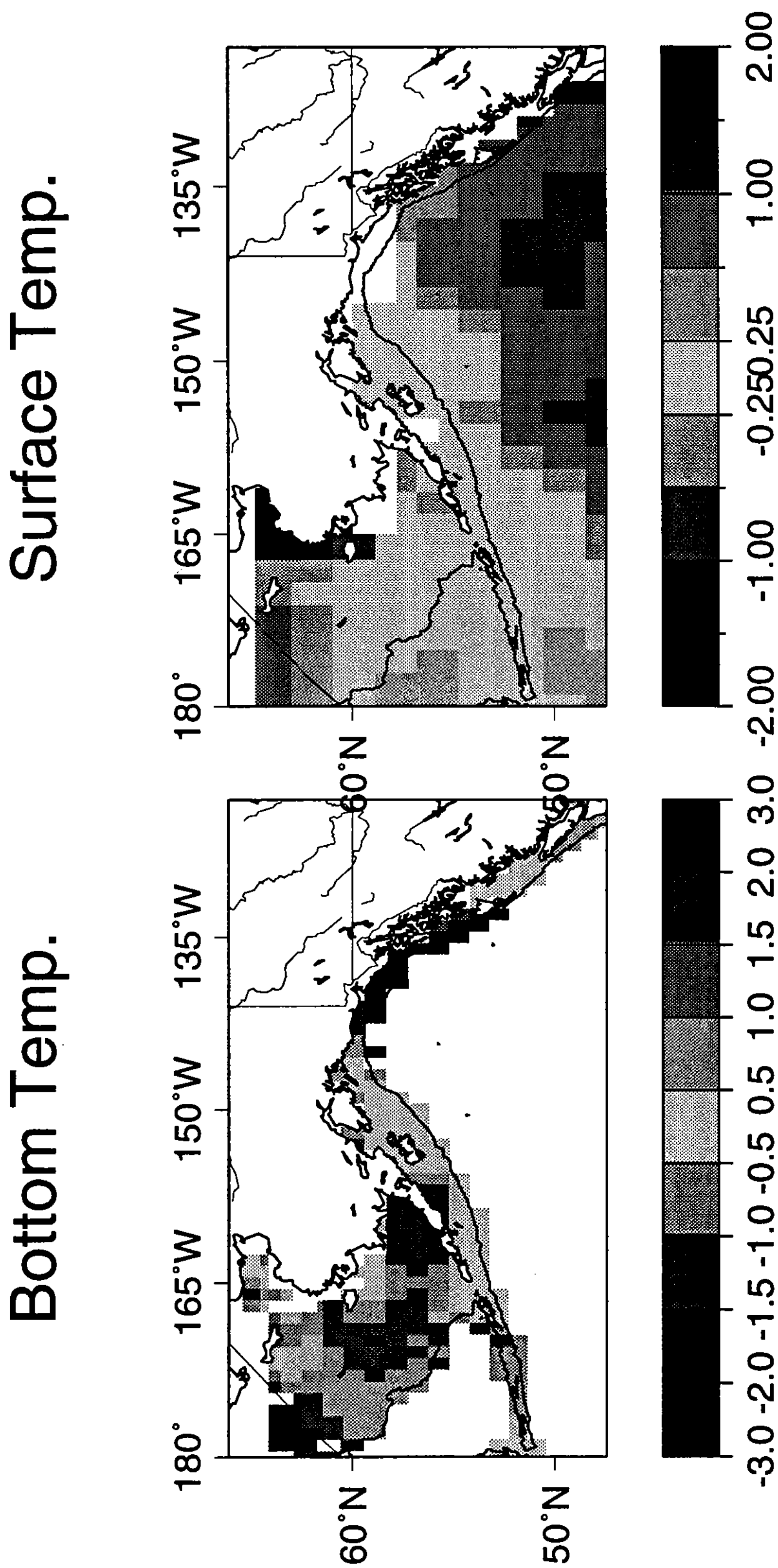
Surface Temp.
Bottom Temp.
180°
165°W
150°W
135°W
60°N
50°N
-2.00
-1.00
-0.25
0.25
1.00
2.00
-3.0 -2.0 -1.5 -1.0 -0.5 0.5 1.0 1.5 2.0 3.0

Figure 6.

Halibut Early Life History Study: Project Status

by

Hanwu Liu, Robert J. Trumble, and Donald A. McCaughran

INTRODUCTION

At the January 1997 Annual Meeting, the IPHC Commissioners approved a one year continuation of the Halibut Early Life History Project, with future work contingent on successful rearing of halibut larvae during 1997. In 1997, our healthy brood stock produced good eggs and larvae. Larvae were well on the way to metamorphosis when a water system failure at the laboratory killed all the halibut larvae, and salmon and herring larvae that were part of other projects. This memo summarizes 1997 achievements and plans for 1998 and the future.

Importance of the Project

This project is one of three proposed for environmental investigations by the IPHC Staff. New information has recently demonstrated that the environment has large effects on abundance and growth of fish populations. The Early Life History project will examine the earliest stages of the halibut life cycle. Several presentations at the Third International Symposium on Flatfish Ecology (November 1996) addressed larval quality and subsequent survival, and potential effects on recruitment. Environment acts on maternal effects and directly on eggs and larvae. Variation in initial larval size, growth rates, larval period duration, and sizes at transition between larval and juvenile stages will affect survival. Presence of absence of maternal effects could have significant implications for the halibut resource. Long term environmental changes appear related to halibut production. Does the environment act on female fitness/progeny fitness and directly on larval/juvenile survival? Knowledge of the biology of Pacific halibut early life history is considered important for the continued effective management of this valuable commercial species.

Achievements

Scientific contributions

Over the course of this project, project personnel have produced one Ph.D. dissertation and 10 journal publications, and made presentations at three national and international meetings.

Healthy broodstock

Our experiences have demonstrated a minimum requirement of three years to establish a healthy halibut broodstock. A long delay between capture and effective spawning is a common phenomenon for many marine fishes. Establishing Atlantic halibut broodstock required about 5 years (Tilseth, 1994). Devauchelle et al. (1988) reported that immature turbot held for two years produced good spawning, while large turbot spawned without success. A similar situation exists for sole (Devauchelle et al., 1987), sea bass (Carrillo et al., 1995), and sea bream (Zohar et al., 1995). After three years of collection and selection, we have established a healthy Pacific halibut broodstock of more than 40 adult fish.

Large scale production of feeding larvae

We can now produce large numbers of feeding larvae. The major requirements for producing feeding larvae are cold water temperature (about 5°C); total darkness; and slow water exchange. In 1997, spawning began around February 24 and continued to May 3. The earliest spawning produced the best survival. Approximately 2,000 of 6,000 larvae survived to first feeding stage when held in the right conditions. Almost 100% mortality occurred for larvae held in sub-optimum conditions. Most of the feeding larvae were used for experiments. Over 300 larvae were feeding and growing well for over 30 days until early June when water supply system to the lab broke down because of bio-fouling in the water line. All halibut, salmon, and herring larvae at the lab died. The halibut larvae were about two weeks from the starting of metamorphosis at the time.

Results from 1997 experiments

Experiments conducted before the system crash that killed all the larvae provided the following results:

1. The time from hatching to first feeding was reduced when the larvae were maintained at a temperature of either 9°C or 11°C as compared with 5°C to 6°C. A further increase in temperature to 13°C proved fatal.
2. Rotifers (*Brachionus plicatilis*) were the preferred first food of halibut larvae offered rotifers, brine shrimp (*Artemia* sp.) nauplii, and wild copepods, either alone on in the presence of phytoplankton (*Tetraselmus* sp.).
3. We hypothesize that broodstock may not produce enough thyroid hormones, and thereby reduce survival of the delicate eggs and larvae. Addition of two thyroid hormones appeared to improve larval survival rates. Neither of the hormones caused abnormalities in developing embryos or in larvae from hatching to age 30 days.
4. There was no observed advantage of providing live food animals (*Artemia* sp. nauplii) in the presence of algae (green water technique) as compared with providing live food in the absence of algae (clear water technique).

Research Proposed for 1998 and Beyond

We are confident that halibut larvae will pass metamorphosis in 1998. Larvae were only two weeks from metamorphosis and growing well in 1997 when the water supply failed. We will improve the rearing system with a new filtration system installed by the Marrowstone Lab and by adding a vertical water current, after first feeding but before metamorphosis, that has increased rearing success in Norway. We propose conducting the experiments 1, 2, and 3 during 1998. Experiments to address maternal effects and thyroid hormone effects are scheduled for 1999. We anticipate preparing proposals to seek grants for the 1999 experiments. Data from a preliminary thyroid hormone experiment in 1997 will form the basis for a proposal to the USDA later this year.

1) Halibut Larval Incubation Temperature.

Pacific halibut larvae hatch in a premature form with a large yolk sac (Forrester and Alderdice, 1973; Liu, 1991). The yolk-sac larvae must be incubated in cold, total darkness for 30 to 50 days depending upon temperature (Liu, 1991). High mortality and high numbers of developmental deformities during this period are problems in producing the Pacific halibut.

Pacific halibut spawn near bottom in temperatures that may range from 1 to 8 °C, as a result of regime shifts combined with normal inter-annual variation. The larvae experience warmer temperatures, in some years over 10 °C, as they rise toward the surface. Evaluation of larval survival and growth with incubation temperature will give us insight into the effects of regime shifts at the earliest stages of the halibut lifecycle.

We propose to incubate Pacific halibut larvae at 4 different temperatures (5, 7, 9, and 11 °C) to determine the effects of larval incubation temperature. We would prefer to include a colder temperature, at least down to 3 °C, but our chiller does not have the capability.

One female and two males will be stripped of eggs and sperm. The eggs will be fertilized and incubated as described by Liu (1991). One day before hatch, about 1,000 embryos will be transferred to a 25-l fiberglass tank for incubation. Four incubation tanks will be placed in each of four troughs that keep each treatment at designated temperature. The desired temperatures will be maintained by adjusting the flow rates of chilled and heated water. Other than temperature all other incubation conditions will be maintained the same. During the incubation water exchange rate will be kept at 30% daily. Ambient seawater will be filtered through 0.2 µm and UV-irradiated. High salinity ($34^{0}/_{00}$) will be obtained by adding commercial food grade salt.

2) Temperature Effects on Halibut Larval Otolith Formation

Halibut otoliths contain information on the effects of environmental change. For example, Hagen and Quinn (1991) found that halibut growth during the first several years of life correlates with sea surface temperature. We anticipate that environmental conditions will record on larval halibut otoliths through variations in naturally-occurring markers on the otoliths. We will evaluate if temperature-induced changes in larval growth cause similar changes in these markers, and compare the otoliths from captive halibut with the otoliths from wild larvae captured by NMFS. To the degree that NMFS can provide temperature at the point of capture, we can see if captive and wild larvae have similar marks at similar temperatures.

Approximately 100 feeding larvae will be reared in triplicated 25-l tanks with low (5°C) or high (10°C) water temperatures maintained by adjusting the flow rates of chilled and heated seawater. Larvae will be fed with copepods and brine shrimp. Samples will be collected at first feeding and metamorphosis for later otolith study. Samples of pre-feeding and post-feeding larvae will be collected for analysis of proximate composition and essential fatty acids in collaboration with NMFS. NMFS will attempt to obtain sufficient wild larvae to compare composition of wild and captive larvae.

3) Photoperiod Effects on Broodstock

Halibut spawn and spend winters at depths of 200 to 500 meters where light is invisible to human eyes. Does photoperiod affect Pacific halibut reproduction? To address this question, we will treat adult halibut with different photoperiods for a year. At the end of the experiment, the spawning percentage in each treatment will be used to evaluate effects. Two groups of four adults (3 females and 1 male) will be held in total darkness, two more groups will be held at normal photoperiod, and two groups at a condensed, 9-month photoperiod. All tanks will be covered with a light-proof layer consisting of a layer of net, a black plastic sheet, and a blue plastic sheet.

4) Maternal Effects (1999)

Presence or absence of maternal effects could have significant implications for the Pacific halibut resource. A link between larger female size and increased larval/juvenile fitness implies that a commercial fishery selective for large females would reduce fitness of progeny. Long-term environmental change appears related to halibut production; if so, how does the environment operate on female fitness/progeny fitness and directly on larva/juvenile survival? Currently we have enough female halibut of different sizes (90 to 130 cm) for this study. More space and labor are needed to track individual females.

5) Thyroid Hormones Effects (1999)

It is generally agreed that thyroid hormones play an important role in early fish development since considerable amounts of thyroid hormones are present in fish eggs and larvae. Recent evidence suggests that thyroid hormones are passed on to eggs by broodfish. This store of maternal hormones may fill the regulatory needs of fish larvae for growth, development, osmoregulation, stress response and other physiological functions prior to the functional development of their own endocrine glands. So far, no data exist on thyroid content of halibut eggs.

Thyroid hormone treatment for accelerating halibut larvae development would likely be successful because the larvae hatch at an extreme premature stage, with no functional eyes, mouth, no pigmentation, and with a large yolk-sac that needs about 50 days to be absorbed. The mechanisms, however, remain undefined. The results of this study may provide an effective means to improve egg quality and shorten larval incubation and rearing period by accelerating the development and growth of the larvae.

Collaboration With Other IPHC Projects

The halibut early life history project may provide samples for the DNA study and for the stable isotope project.

<u>DNA</u>

Using samples from the halibut early life history project it may be possible dovetail a number of interesting biological questions with the current research.

1. Mendellian Inheritance - To determine whether halibut follow standard inheritance samples would be needed from a 1:1 spawning (parents and offspring). This is a standard test that confirms the inheritability of the primers.
2. Quality of Spawn - By typing individual fish that are contributing to a controlled spawn it would be possible to determine the percentage contributed by each fish to the viable offspring.

3. Sex determination - Many primers have been developed from the male chromosome. This allows typing of individuals to determine sex. This could be matched with otolith samples to determine the sex of the fish where the age-length relationship cannot separate the fish.

Stable Isotopes

Stable isotopes of oxygen, carbon, and nitrogen deposit in fish otoliths at different ratios depending on environmental and other factors. Oxygen is the primary element, as it has the most potential to track temperature changes, but other elements may also provide useful information. The Early Life History Project has halibut adults (and later will have larvae and juveniles) held under known temperature and salinity conditions. Temperature and salinity both affect the ratio of isotopes deposited in the otolith, and known samples are required to calibrate environmental effects on ratios.

Facilities Needed for Next Research Stage

Experiments to date have occurred with small scale facilities. Enhancement of the facilities to permit large scale experiments was planned for after establishment of healthy broodstock and demonstration of probable success with future experiments.

We cannot use enough of larvae produced to conduct planned experiments. In 1997, about 50,000 larvae hatched from over 1 million eggs. Most of the eggs were wasted because of limited space. We drained the spawning tank several times a week to flush out the unused eggs. We predict several million eggs in 1998.

We need at least 1,000 metamorphosed larvae to conduct the experiments for 1998, which requires expanding the larval rearing space to about 600 square feet of insulated space with a series of larval rearing tanks. The Marrowstone Lab has agreed to provide the space. The cost for insulating the space and purchasing the tanks is about $20,000.

The Marrowstone Lab will solve the water supply system problem by installing a sand filtration system. The IPHC will fund labor for the installation as part of our utility payment.

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An Investigation into the Occurrence and Causes of the Chalky Condition in Pacific Halibut

by

Steve Kaimmer

INTRODUCTION

Prior to the 1997 Annual Meeting, Commission staff were notified that chalky halibut would be an item of discussion during the meeting. To prepare for this, a literature review was conducted and made available to industry members and Commissioners prior to that meeting. In shortest summary, the review indicated that the majority of work in chalky halibut, or chalky fish in general, was conducted during the 1960's by the IPHC and the Pacific Biological Station in Nanaimo, B.C., Canada, and that subsequent articles discussing chalky halibut for the most part simply paraphrased the results of those reports. During the 1997 Annual Meeting, the Processors Advisory Group (PAG) identified chalky halibut as a concern and the Commission directed the staff to conduct an investigation of chalky halibut. Working with PAG, a study format was developed which identified three components for study; 1) to determine the incidence of chalky halibut during the 1997 season, 2) to investigate the cause of chalky halibut, and 3) to study methods to detect, avoid and/or reduce the occurrence of chalky halibut for the future.

MATERIALS AND METHODS

A working group made up of PAG members agreed that more specific information on the occurrence of chalky halibut was required before any field project could be designed. To this end, our efforts during 1997 have focused on a series of surveys to more fully document the occurrence of chalky halibut, both over time and area, and on continuing to survey the available literature to develop a physiological description of the chalky condition.

Initial survey- "1996 experience with chalky halibut"

An initial survey questionnaire was developed by the staff, working with the PAG working group. The survey was designed for response by all components of the industry; including fishermen, fish buyers and processors, fish brokers, and retail users. The survey identified the responding company, and detailed past experience with chalky halibut. Questions were directed towards whether chalky halibut had even been seen in the past, and asked for an estimate of chalky halibut encountered during the previous fishing year, 1996. Respondents were also asked whether they would participate in our study by returning chalky halibut incident report forms (see next section). As well, ideas or suggestions for research not covered in the survey questions were solicited.

Chalky halibut incident report form - 1997 occurrences of chalky halibut

Provided with the initial survey was a form intended to document all occurrences of chalky halibut during 1997. Respondents were asked to duplicate this form, fill one out for each observed occurrence of chalky halibut during 1997, and either mail or fax them to the IPHC office before the end of the year.

Second Survey - "1997 experience with chalky halibut."

Near the end of the 1997 fishing season, a second questionnaire was send out to summarize 1997 experiences with chalky halibut. This survey was very similar in format to the one mailed out at the start of the year which requested a summary of experiences during 1996.

RESULTS

Using IPHC address files, both survey mailings were sent out to media, fisher's groups, all all individuals which had bought halibut during 1996. We received 22 responses from the initial survey and have so far received 14 responses from the second survey. Six companies responded to both the first and second surveys. A total of 30 companies responded to either one or both of the surveys. We have had 53 chalky fish occurrence forms filed.

Initial survey

Responses are as follows:

2 respondents identified themselves as fishermen, 15 as buyers or processors, 1 as a broker, and 1 as a cold storage.

Of 16 respondents indicating IPHC area, only 2 indicated buying from areas 2A or 2B, 7 for 2C, 15 for 3A, 8 from 3B, and 4 from areas 4 (totals more than 16, since some respondents have activity in more than one area).

17 have seen chalky fish before, 14 in 1996, and it is an "issue" for 11 of the respondents.

14 indicated amount of chalky fish seen in 1996, ranging from 0.0 to 6.3 percent of fish handled, overall less than 29,000 pounds out of 7.7 million, about 0.4 percent.

5 respondents indicated that they identified chalky halibut at time of delivery, 12 during later processing in the plant, and 10 by later claims from buyers. Comments seem to indicate that chalky fish is seldom recognized at the buying plant when fish are shipped whole, either fresh or frozen. Comments also indicate that while some chalky fish are identified during fletching operations at the buying plant, most chalky fish are identified by later claims.

1997 chalky halibut incidents

Thirteen respondents, responsible for over 7.5 million pounds production in 1996, indicated that they would file chalky fish incident reports during 1997. Chalky incident reports have been filed by eight companies, for a total of 53 reports (31 by one company, 9 by second and 7 by a third).

A total of 10,000 pounds of chalky fish has been reported, being observed in total deliveries of 780,000 pounds, an overall incidence of 1.3 percent in reported landings which had at least some chalky fish. The amount of chalky fish in any one delivery was as high as 90 percent, although that was a total delivery of just over 500 pounds. Percent of chalky halibut in deliveries which contained some chalky halibut averaged 7.7%. In all cases fish was chilled at delivery. State of bleeding, icing on board, and dressing was not commented on. In one case, the same boat had delivered chalky fish the previous year. No occurrences have been reported from Area 2A, 1 from Area 2B, 32 occurrences were identified as from Area 2C, 11 from Area 3A, 3 from Area 3B and 1 each from Areas 4A and 4C.

In only one case was the chalky fish identified at the plant. In 50 cases the fish was identified by a claim from a downstream buyer. In 14 cases, the downstream buyer refused the fish and in 38 cases the result was a price adjustment on the amount of fish which was chalky, ranging from paying a reduced price to not paying anything for the chalky fish.

I have heard secondhand of some chalky fish delivered more recently, but have received no incident reports on this fish.

Final survey

Responses are as follows:

There have been 15 responses to the second survey. Eleven respondents identified themselves as buyers or processors, 1 as a broker, 1 as a cold storage, and 2 as retail sellers.

Fourteen of the respondents indicated IPHC area. One buys halibut from Area 2A, two from Area 2B, six from Area 2C, eight from Area 3A, five from Area 3B, and indicated buying from areas 2A or 2B, 7 for 2C, 15 for 3A, 8 from 3B, and five from Areas 4 (totals more than 14, since some respondents have activity in more than one area).

Eight have seen chalky fish before 1997, nine in 1996, and it is an "issue" for six of the respondents. It is "not an issue" for five of the respondents.

14 indicated amount of chalky fish seen in 1996, ranging from 0.0 to 2.4 percent of fish handled, overall about 124,000 pounds out of almost 17 million pounds, about 0.75 percent, overall. There was some trend for higher proportions of chalky fish in the more southern areas. Overall, chalky fish proportion in Area 2 ran about 1.0 percent, while chalky fish in Area 3 ran about 0.5 percent.

One respondent indicated that they had identified chalky halibut at time of delivery, four during later processing in the plant, and six by later claims from buyers.

Six of the respondents indicated the result of the chalky fish occurrence was either a price reduction to the buyer, or a adjustment to the total pounds sold to reflect a removal of the pounds of chalky fish.

DISCUSSION

The general trend suggested by the 1996 survey appears to continue. The 0.5 percent incidence in the U.S. is comparable to that estimated from the previous survey, while the 1.0 percent in Canada is new information. Some amount of chalky halibut has been reported for all IPHC areas, and for all months of the fishery, with reports from area 2C both early and late in the year, and reports from Area 3A during the middle of the season. Anecdotal reports would suggest that there may be a trend of increasing occurrences into the middle of the summer, with occurrences tapering off during the fall. The surveys included space for comments on topics not covered directly by the survey questions. One comment which was stated in different ways on more than one questionnaire was that our results should not considered to be representative of the entire fishery. One reason for this caution stems from the nature of the halibut processing industry. Many fish, probably more than half of the entire production, are not cut at the buying plant beyond removal of the head. The whole fish are either shipped fresh to wholesale buyers or frozen for the same market. In many cases, this makes it difficult or even impossible to determine whether the fish is chalky until after it is sold. While most of the chalky fish reported was recognized through claims by subsequent buyers, it is possible that a large proportion of chalky fish goes unreported. It is also possible the chalky fish goes purposely unreported, in an effort to make the problem seem less than it might. We have no way of determining whether either of these biases in fact exist, and, if so, the degree to which they might effect our results.

Chalky halibut has occurred in the directed halibut fishery for a least 30 years. Research directed at this problem dates back to the late 1960's, when a series of field projects established a link between acidity buildup caused by capture stress and the post mortem development of the chalky condition. Our current surveys have demonstrated that the occurrence of chalky halibut is widespread over the range of the fishery, both in terms of area and timing. While our surveys represent about 8 and 17 million out of landings of around 60 million pounds in both 1996 and 1997, respectively, it is not clear that we can directly extrapolate percentages from those subsamples up to the total landings for each year. Where such extrapolations are made, they should be presented cautiously.

Various reasons have been suggested for the onset of chalkiness. In general, it appears that a fish which dies from, or in a state of, exhaustion, will have a high degree of lactic acid, a byproduct of exhaustion, in the muscle tissue. This exhaustion could be caused by intense exercise prior to or during the capture process, or possibly by temperature or air exposure while lying on deck prior to dressing. While a reading of the literature suggests that proper handling of setline halibut can reduce the development of chalkiness, in no case is there any indication that fish handling can stop or reverse the development of chalkiness once the fish dies in an exhausted state. Video observations of halibut hooking indicate that halibut swim vigorously once hooked and then go through a series of resting and darting behaviors prior to longline retrieval. A freshly hooked fish may be in a higher state of exhaustion than one which has been captured for a longer period of time. Certainly, trawl caught fish have a much higher rate of chalkiness than those caught on longline.

Overall, the incidence of chalkiness appears to be on the order of about a half to one percent, with some trend to higher chalkiness during hotter months. It is possible that either higher water temperatures, or higher air temperatures during capture either increase capture stress or in some way accelerate the chalky process. A most unfortunate part of this problem is the timing of the onset of the chalky condition. Halibut are not chalky when they are killed. The early studies demonstrated that chalkiness developed in iced product 3 to 7 days after death, and the condition could develop after thawing at a much later date in fish which were frozen. While it may not be possible to eliminate chalky halibut from our fishery, a method to determine the tendency for chalkiness at dock delivery would be most advantageous.

CONCLUSIONS

When applied to total landing figures, an overall incidence of one-half to one percent could represent three to six hundred thousand pounds of chalky fish being sent to market. It is possible that increased diligence by fishers can reduce the occurrence of chalky fish. For the most part, fishers now are very aware of procedures to maximize quality of landed product, and our studies have not yet suggested any changes in these procedures which would minimize chalkiness. A possible exception could be in encouraging the stunning of fish on landing, to reduce a continuation of stress between capture and dressing. Many fishers do this now. There is only the weakest pattern in area and time of chalky fish occurrence, the suggestion that chalkiness is more common during hot months, or from the more eastern areas. While it would be possible for the IPHC to conduct field investigations of factors associated with chalkiness, no practical design has been suggested by our recent investigations. We received no reports of chalkiness in the over 1 million pounds of fish delivered by our 1997 setline surveys, which represented short and long soak times, shallow and deep sets, deliveries from throughout the halibut's range and from June through August. In some cases, the magnitude of the catch at an individual station resulted in fish lying, sometimes unstunned, for one or two hours before dressing. It is possible that chalkiness is a fact of the fishery, even when fish are handled as well as possible.