Selective Fishing Demonstration Project

FINAL PROGRESS REPORT

Prepared By:

Jake Duncan

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June 1, 2010

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Prepared for:

Northern Climate ExChange

ACKNOWLEDGEMENTS

I would like to acknowledge the assistance of Sebastian Jones, Northern Climate ExChange’s Local Adaptation Coordinator. Without Sebastian’s help and assistance this project would not have been possible. I would also like to acknowledge previous projects towards selective fishing in the Yukon via the Yukon River Panel’s Restoration & Enhancement Fund. This project builds on these earlier efforts towards the adoption of more sustainable harvesting practices, which will ultimately benefit a valuable local food source and those that depend upon it.

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EXECUTIVE SUMMARY

Yukon River Chinook salmon are well known for certain characteristics, specifically their richness which comes from their high oil content and their enormous overall sizes. Both are evolutionary features the species has developed to handle one of the world's longest migrations of over 3,300 kilometers (2,000 miles). While the distance these fish travel hasn't changed over time, their overall sizes have, which is an indication of unsustainable fisheries management. Chinook salmon returning to the Yukon River vary greatly in age and size. While Chinook salmon tend to return on average at the age of 6, runs are made up of 3, 4, 5, 6, 7 and 8 year-old fish and fish sizes vary accordingly. Therefore, if a fisher uses a large meshed gillnet, they tend to target and capture larger, older and heavier chinook; conversely, should they choose a smaller meshed gillnet, they would tend to capture smaller, younger and lighter fish. Biologically, in the case of Chinook salmon, older and consequently larger 7 and 8 year old fish are disappearing from runs. These fish are by far the most productive within the population and their absence may be signaling a serious biologic stock failure as well as an overall reduction in productive capacity. If the more productive older/larger and female fish were safely released, and generally not targeted, the quality of escapement would increase and the fishery would be much more sustainable. The Yukon River Chinook fishery is a high quality local food source that would benefit from higher, more sustainable harvesting practices. This project is about developing guidelines and protocols while demonstrating selective fishing practices with the use of live-capture/release fishwheels. The objective is to develop fishing methodologies and incentives whereby older, larger, and more productive female fish are not targeted or harvested.

BACKGROUND

Traditional gillnets have evolved over many centuries as a highly effective tool for catching fish. Gillnets are lethal to fish and they target species by targeting their size. Fish that are smaller than the targeted mesh-size tend to avoid capture by swimming through the larger meshed nets, and larger fish tend to avoid capture by 'bouncing off' the smaller sized mesh.

Chinook salmon returning to the Yukon River vary greatly in age and size. While chinook salmon tend to return on average at the age of 6, runs are made up of 3, 4, 5, 6, 7 and 8 year-old fish and fish sizes vary accordingly. Just as designed, if a fisher uses a large meshed gillnet, they would tend to capture larger, older and heavier chinook; conversely, should they choose a smaller meshed gillnet, they would tend to capture smaller, younger and lighter fish.

Given the above, if harvesting was restricted to an overall number of fish (ie. not at any one size), which gillnet would you choose? Since commercial catches are only limited or managed to the number of fish harvested and not to the level of size/age, or sex restrictions, commercial fishers naturally tend to target larger fish in order to increase the overall weight of their catches. This is accomplished by utilizing large meshed gillnets that are designed to target larger fish and these gillnets are lethal to fish captured.

Biologically, in the case of Chinook salmon, older and consequently larger 7 and 8 year old fish are disappearing from runs. These fish are by far the most productive within the population and their absence may be signaling a serious biologic stock failure as well as an overall reduction in productive capacity. If the more productive older/larger and female fish were safely released, and generally not targeted, the quality of escapement would increase. It is well known by fisheries managers worldwide that declining size in a harvested population of fish is the first sign of catastrophic stock failure.

Typically, Selective Fisheries techniques are used to avoid non-target or endangered species. In the upper Yukon River, the mixing of migrating salmon species during harvesting periods is not typical; however, there are sizes/ages of fish that are endangered within the chinook species, and issues with the size-selectivity of gillnets as observed through the decreasing overall size of chinook salmon (Appendices A & B - JTC Appendix Table A10 – complete absence of 8-year old fish, serious reduction in the number of 6 and 7-year old fish returning, increase of the proportion of 5 year-old fish).

The technology exists to live-capture and safely release salmon. The main factor standing in the way of simply imposing a slot limit or a regulation on size and/or sex retention are essentially the will to do so, or support for a change in management; especially given the obvious increases to harvesting effort required, and the simultaneous reduction in retained catch that releasing female and large fish would create. In order to gain support for this idea, from both a fisher and fish manager perspective, other essential details such as live-handling & release protocols and guidelines need to be developed and agreed upon, as well as retention standards or slot limit sizing, approved equipment, and licensing terms. Incentives must also be found to help convince fishers of the advantages in becoming selective in their catch.

If the focus of previous selective fishing projects were on ***convincing*** fishers it was possible to use fishwheels to harvest chinook salmon - this project is about ***converting*** fisheries over to full selective fishing operations and demonstrating it viability, while working on the remaining obstacles (approved protocols, practices, and regulations/guidelines – as well as support) to enable this positive evolution in harvesting practices to take place.

DESCRIPTION OF PROJECT

Over the winter of 2009-2010, background materials were gathered, reviewed, and researched. Introductory meetings were held with DFO officials and a supporting application to the Yukon River Panel's Restoration and Enhancement Fund (R&E Fund) was developed. Draft guidelines were introduced to DFO personnel and all preparatory work was performed. Preparatory work included: finalizing designs of fishwheels and all live-handling equipment, gathering local hardwood lumber, producing jigs for parts construction, and, the acquisition of other materials.

In the spring of 2010, three light-weight, easily deployable, live-capture fishwheels will be assembled. These live-capture fishwheels are intended to completely replace traditional (lethal) gillnets and avoid non-target fish (large & female chinook). They will be tested during the 2010 chinook season. Live-handling equipment such as pens, cradles, and shoots will be tested alongside the live-capture fishwheels and diagrams will be made available for review.

Should enough fish return in 2010 to allow a commercial fishery, the live-capture fishwheels will be used in a demonstration project where all large (above the developed retention size limit) and female chinook will be live-released. Data will be gathered and other metrics, such as catch per unit of effort will be analyzed. Recommendations for incentives supporting selective fishing will be developed.

The proponent will work with DFO biologists to develop retention limits (slot limits), and live-handling & release protocols for selective fisheries, and acceptable Conditions of License and/or regulation changes to allow selective fishing to take place in a controlled and enforceable manner. Results will be shared with other users through workshops, presentations, meetings, and information sessions on an ongoing basis. It is expected that these exchanges will continue throughout the winter of 2010-11 and beyond.

PERSONNEL

Jake Duncan is a Yukon River commercial salmon fisher (License #471) who has been fishing on the Yukon River seasonally for 20-years. Jake has been involved with many Canadian R&E projects and has been employed as a Habitat Steward and a Yukon Stewardship Coordinator. Jake has also served on the Dawson District Renewable Resources Council (1999-2002), and worked for other co-management entities such as the Yukon Salmon Committee and the Yukon Fish & Wildlife Management Board. Jake currently works as a Natural Resource Technician with EDI Environmental Dynamics in Whitehorse and as a self-employed business person. As a resource technician he assists EDI with a variety of natural resource projects and is instrumental in the high quality work they do. As a self-employed business person, his businesses have received local (2009 Yukon Exporter of the Year Award), regional (Yukon Business Development Project 2008), and national recognition for innovation and sustainable resource use (2007 Canadian Design Exchange Award, 2006 Export Award for Industry Innovation – Fur Is Green, connecting fur to wildlife habitat conservation and stewardship). Jake has done a lot of volunteer work over the years and his businesses contribute to many social and environmental causes. Jake lives in Dawson City with his partner Megan Waterman and their two young children aged 4 and 8.

Jake has worked closely with DFO biologists and enforcement personnel in orienting draft regulations and/or Conditions of License, as well as guidelines, standards and other project details and plans. Fishwheels will be constructed locally (Dawson City) with local in-kind and local labour. Data collection will be completed alongside regular commercial fishing openings, if the opportunity is present in 2010. Additional data will be collected with volunteer assistance from commercial license #420 (ie. net vs. fishwheel catches, lengths, sex, etc.) for comparison purposes.

Jake will work with DFO and the YSC to develop Selective Fishing Guidelines, policy and/or regulations. Jake will also work with DFO, YSC, and other co-management entities, as well as commercial fishers to advocate for the adoption of selective fishing practices, this will likely include presentations, workshops and/or information sessions.

SCHEDULE

Research and Planning, Policy/Protocols (Complete) January-June 2010

Background material was researched and gathered. Meetings were held with DFO personnel including Stock Assessment and Enforcement to identify issues, concerns, and knowledge gaps. A supporting application to the Yukon River Restoration & Enhancement Fund (R&E Fund) were prepared.

Fishwheel Construction Prep. (Complete) January-May 2010

Local materials were gathered (ie. Birch hardwood) and jigs are in the process of being made. Final plans are being drafted and preparations for construction have been made.

Fishwheel Construction June-July 2010

Three fishwheels will be constructed. Live-handling pens and related gear will be made. All fishing gear will be brought to fishing sites and made ready to fish should there be enough fish returning to support commercial openings in 2010.

Testing, Demonstration & Data Collection July-August 2010

Fishwheels will be operated in a selective fishing manner during openings in 2010. Information and data will be collected and used for presentations and reports.

Workshops, Presentations, Info Sessions Sept-December 2010

During the off-season, workshops, presentations and information sharing sessions will be organized with the YSC, commercial fishers, and other interested groups (ie. RRCs).

Reporting December 2010

A final report will be prepared (YRP) that will include discussion on how selective fishing practices can be adopted in Yukon. Suggestions and recommendations will be developed for discussion.

RESULTS & DISCUSSION

Early in January an application to the Yukon River Panel's (YRP) Restoration & Enhancement Fund (R&E Fund) was prepared. This funding partner and the technical representatives were contacted and the project was discussed at length. Several other DFO representatives were corresponded with to discuss the legal/Enforcement, stock assessment and technical issues. YRP technical representatives were contacted throughout their review of the project and during the YRP decision-making process. In summary, we were successful in accessing funding from the YRP R&E Fund that greatly leverages NCE funding, and the external (to YRP) NCE funding was very instrumental to this.

Background and supporting information regarding selective fishing guidelines and methodologies has been collected from various sources and this effort continues. During the funding process, the focus on regulatory became obscured as DFO has expressed an interest in developing these themselves. At several junctures is was suggested that a discussion paper be prepared that delves into or suggests possible guidelines and regulations. Much work was done to this end and this information will compliment future presentation and workshop materials. In the end, it was determined that funding would not be linked to the development of guidelines and regulations, rather to the construction and demonstration of fishwheels.

Much work has been done to prepare for the construction of fishwheels, such as the harvesting of local birch trees, the milling of local birch trees, the development of jigs to fabricate wooden parts, and the gathering of materials and supplies. The remainder of fishwheel construction is planned to take place between June and July.

RECOMMENDATIONS

Despite the change in focus from developing guidelines and regulations to the demonstration of selective fishing with fishwheels, it is highly recommended to stay involved in the regulatory process. In Yukon as a result of the land claims process and the UFA, regulations are developed in co-management and many opportunities exist to participate in the development of regulations and protocols. Also, through the continuation of demonstration and the adoption of selective fishing harvesting methods, a positive example will be observed. It is recommended that the techniques and equipment developed as part of this project should be utilized to their fullest extent long into the future to provide this positive example.

The following are specific recommendations in point form:

Fishwheels & Live-handling Gear:

1. Consider the use of modular plastic pontoons, e.g. http://www.plasticpontoon.com/web/24.html
2. Make additional baskets to stay ahead of need for repairs in subsequent years.
3. Develop CAD drawings of final designs for distribution.

Guidelines & Regulation:

1. Develop and maintain several Powerpoint presentations to illustrate objectives, at various lengths for various audiences.
2. Suggest options and opportunities to DFO & the YSSC
3. Be available and prepared for workshops, presentations, and info sessions, should they be desired from co-management entities.

REFERENCES

D.Conover, S.B.Munch, and M.Walsh. *Darwinian Fishery Management: Rapid Evolution of Somatic Growth and Yield in Experimentally Harvested Marine Fish Populations.* Marine Sciences Research Center. Stony Brook University 2002 (Appendix C)

T.O. Haugen and L.A. Vøllestad. *Effects of Variable and Size-Selective Gill-Net Fishing on Life-History Evolution in Grayling*. T.O. Haugen and L.A. Vøllestad. Department of Biology, University of Oslo. 2002

A Policy for Selective Fishing in Canada's Pacific Fisheries - February 2001
http://www.dfo-mpo.gc.ca/Library/252358.pdf

Canadian Code of Conduct for Responsible Fishing Operations (Appendix D)
http://www.dfo-mpo.gc.ca/fm-gp/policies-politiques/cccrfo-cccppr-eng.htm

Fishing Salmon Selectively [Report on the November 1998 Technical Workshop]
http://www.dfo-mpo.gc.ca/Library/231464.pdf

Selective Fishing in Canada's Pacific Fisheries - A New Direction - May 1999
http://www.dfo-mpo.gc.ca/Library/235880.pdf

DFO WAVES Library Search Results (Appendix E)

LIST OF PHOTOS

Photo 1. A Fish Wheel on the Chena River

Photo 2. Historic Fish Wheel on the Yukon River, 1904

Photo 3. Gathering Materials – Reusable Plastic Drums for Floatation

Photo 4. Gathering Materials - Milling Local Birch for Fish Wheel Baskets

APPENDICIES

Appendix A10.–Yukon River Canadian Chinook salmon total run by brood year, and escapement by year, 1982–2002 based on 3-Area Index, Eagle Sonar (2005–2007), and radio-telemetry (local) (2002–2004).

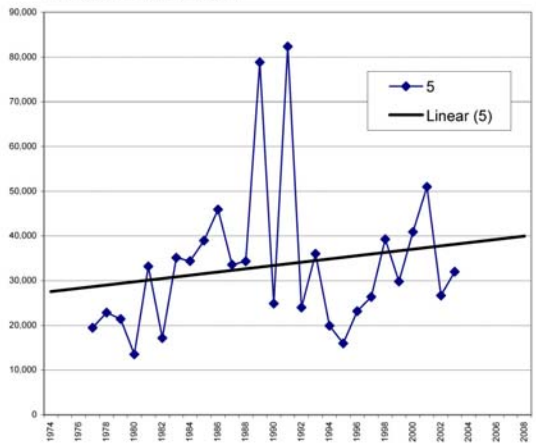
Brood	Age								
Year	3	4	5	6	7	8	Return	Spawners	R/S
1974						634			
1975					33,080	175			
1976				88,405	22,026	40			
1977			19,491	111,771	19,734	801	151,797		
1978		4,443	22,845	63,235	29,424	1,493	121,439		
1979	1,534	3,388	21,422	100,503	48,253	1,175	176,274		
1980	15	6,604	13,510	70,415	33,978	4,240	128,763		
1981	0	1,122	33,220	114,180	54,845	1,841	205,208		
1982	0	5,141	17,169	37,883	27,763	376	88,330	43,538	2.03
1983	560	7,558	35,117	89,449	16,408	162	149,253	44,475	3.36
1984	69	13,368	34,379	75,041	13,782	138	136,778	50,005	2.74
1985	223	10,738	38,956	62,142	4,756	91	116,906	40,435	2.89
1986	347	20,408	45,928	109,067	15,843	138	191,731	41,425	4.63
1987	0	2,368	33,542	67,697	11,700	18	115,325	41,307	2.79
1988	0	6,641	34,323	75,396	8,937	68	125,366	39,699	3.16
1989	75	13,517	78,826	128,851	25,841	0	247,110	60,299	4.10
1990	56	6,343	24,873	71,641	10,816	9	113,738	59,212	1.92
1991	501	7,108	82,332	121,590	10,104	0	221,635	42,728	5.19
1992	6	2,608	23,981	41,407	1,831	0	69,833	39,155	1.78
1993	14	5,313	35,999	86,880	5,880	0	134,086	36,244	3.70
1994	0	730	19,932	30,684	6,175	0	57,521	56,449	1.02
1995	34	1,784	15,989	52,717	7,026	10	77,559	50,673	1.53
1996	20	276	23,199	44,463	14,609	2	82,569	74,060	1.11
1997	14	3,567	26,386	94,407	7,811	14	132,200	53,821	2.46
1998	0	3,478	39,259	76,446	4,376	0	123,559	35,497	3.48
1999	133	1,692	29,791	77,011	2,880	5	111,514	37,184	3.00
2000	0	5,693	40,882	63,607	2,348	0	112,531	25,870	4.35
2001	0	1,818	50,973	48,127	2,566	0	103,483	52,564	1.97
2002	76	2,265	26,711	20,527	3,996	0	53,576	42,359	1.26
2003	63	5,677	31,998					80,594	
2004	0	1,510						48,469	
2005	0							68,551	
2006								62,933	
2007								34,903	
2008								34,008	
Average	**1982-2002**						**122,124**	**46,048**	**2.78**

Contrast	**2.86**

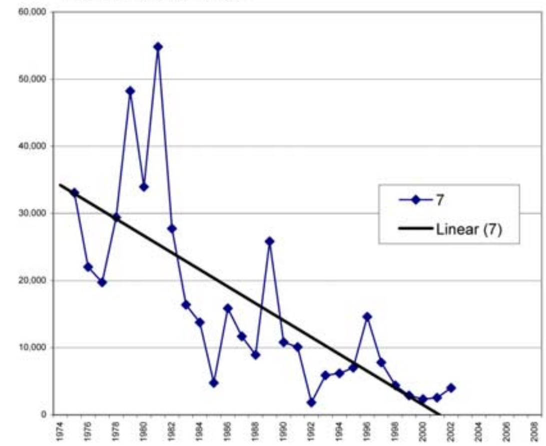
Note: Data highlighted in grey are preliminary.

Appendix B

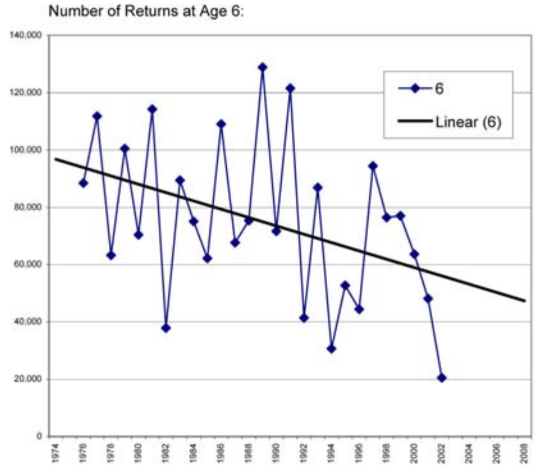
Number of Returns at Age 5:



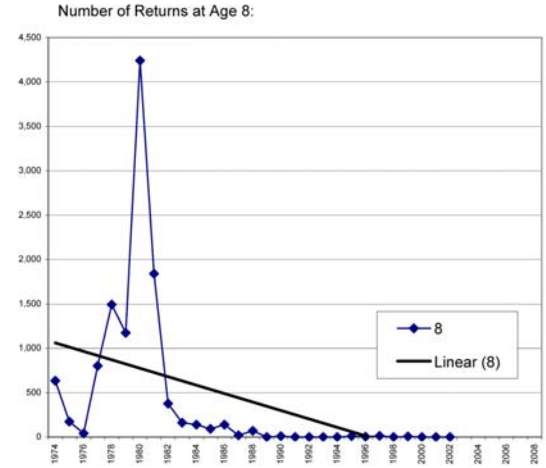
Number of Returns at Age 7:



Number of Returns at Age 6:



Number of Returns at Age 8:



Appendix C

CM 2002/Y:07

Darwinian fishery management: rapid evolution of somatic growth and yield in experimentally harvested marine fish populations

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Fishery management regimes encourage selective harvest of the larger and faster growing members of a population, yet ignore the potential for evolutionary change in harvestable biomass and other traits. To empirically model this process, we subjected six replicate populations of a marine fish (*Menidia menidia*) to large, small, or random size-selective harvest of adults over five generations. Harvested biomass evolved rapidly in directions counter to the size-dependent force of fishing mortality. Large-size-harvested populations initially produced the largest catch but quickly evolved a lower exploitable biomass than controls. Small-size-harvested populations did the reverse. By generation four, the yield from small-size-harvested lines was two-fold higher than in large-size-harvested lines. These shifts were caused by selection of genotypes with slower or faster rates of growth, not changes in survival. Change in growth among lines was positively correlated with change in intrinsic rates of energy acquisition: i.e., faster growing lines evolved higher food consumption rates. Our results illustrate the need to account for evolutionary dynamics in devising plans for long-term sustainable harvests.

Keywords: countergradient variation, growth rate, life history, evolution, size-selective harvest, selection, genetics

Introduction

There is ample reason to expect that the life histories of fish will respond to selective pressures imposed by fishing. Fisheries impose mortality rates several times higher than natural rates of mortality and tend to focus this mortality on large sizes and older age classes. Several recent studies have documented substantial changes in the life histories of fish species for which intense fisheries have existed for prolonged periods (Rochet et al. 2000; Harris and McGovern 1997; Haugen and Vollestad 2001; Sinclair et al. 2002). These changes are consistent with predictions from life history theory for populations experiencing an increase in mortality or size-selectivity. However, for every example noted in wild populations, a plethora of non-evolutionary explanations exist. For instance, apparent decreases in age at maturity may simply be due to removal of late-maturing fish as a result of fishery-related truncation of the age distribution. Similarly, changes in growth rate may be the result of selective removal of fast growers from the population with no concomitant evolutionary response. Other non-genetic explanations include changes due to phenotypic plasticity. For example, decreased age at maturity may simply be a plastic response to increased per capita food availability at low population density (Rochet 1998). Distinguishing among these alternatives in wild populations is difficult if not impossible. Moreover, the pervasive view in fisheries biology is that evolution is simply too slow to account for the observed trends in life history characters. What is needed to address this issue is an experimental approach in which the rate of evolution in response to different harvest regimes may be estimated in the absence of confounding environmental changes.

For evolution to occur there must be heritable genetic variation. While there are few applicable estimates of the heritability of life history traits in the wild, there is ample evidence of extensive local adaptation in these traits (Conover and Schultz 1995). For instance, we now know that numerous fishes display latitudinal clines in intrinsic growth rate. Since the gradient in growth rate opposes the gradient in the seasonal opportunity for growth, this pattern is known as counter gradient variation (CnGV). CnGV has been found for example, in Atlantic halibut (*Hippoglossus hippoglossus*, Jonassen et al. 2000), Atlantic salmon (*Salmo salar*, Nicieza et al. 1994), and striped bass (*Morone saxatilis*, Conover et al. 1997). The existence of genetic variation in growth across natural ecological gradients constitutes proof that production traits of fishes are capable of evolving in the wild. The genetic variation necessary for evolution in response to fishing therefore exists in exploited populations. But at what rate would the yield and biomass of harvested populations evolve under the pressure of size-selective harvest?

An evolutionary size-selective harvesting experiment

We recently conducted the first experimental demonstration of the evolutionary response of marine fish populations to harvesting (Conover and Munch 2002), using as an empirical model, the Atlantic silverside, *Menidia menidia*. The Atlantic silverside is a small neritic species found in estuaries throughout the eastern coast of North America from Florida, USA to New Brunswick, Ca. This species has life history traits that are common to many other marine harvested species: i.e., high fecundity, small eggs (1 mm), no parental care, pelagic larval stages, zooplanktivory, and obligate schooling. Its short generation time (1 yr) and ease of culture in large numbers over multiple generations in captivity make it an ideal subject for experimental evolutionary studies.

We simulated three kinds of fisheries: 1) those in which only the largest fish are taken (largest 90% harvested); 2) those in which only the smallest fish are taken (smallest 90% harvested) and 3) those in which the fish are removed from the population randomly with respect to size (90% randomly harvested). Each population consisted of about 1,000 fish at the time of harvest. Harvest occurred at the adult stage (on day 190 post-fertilization) just prior to spawning. Hence, spawning stock sizes were about 100 fish per population. Each kind of fishery was carried out on two independent replicate stocks for a period of five generations. The changes in mean size that resulted from each of these 'fisheries' was used to determine the rates at which population yield and yield-per-recruit would evolve in response to fishing and provided an estimate of the proportion of variation in growth that is attributable to genetic effects. Changes in survival were also measured in each experimental stock. In order to elucidate the physiological mechanisms by which growth evolves in response to fishing, we also measured correlated changes in a suite of physiological traits related to growth rate. Details of our techniques are described elsewhere (Conover and Munch 2002).

The evolutionary response to size selective harvest was both swift and dramatic (Conover and Munch 2002). Size at harvest increased across generations in the small size harvested lines and decreased in the large size harvested lines (Fig. 1). Hence, large-size-harvested populations initially produced the largest catch but quickly evolved a lower exploitable biomass than controls. Small-size-harvested populations did the reverse. By generation four, the yield from small-size-harvested lines was two-fold higher than in large-size-harvested lines (Fig. 2) These shifts were caused by selection of genotypes with slower or faster rates of growth, not changes in survival (Conover and Munch 2002).

The estimated heritability for length on day 190 (the day of selection) was 0.198 ± 0.013 ($p < 0.0001$) (estimated according to Hill 1972). The heritability estimate was slightly greater for the upward selected line (0.241 ± 0.028) than for the downward lines (0.178 ± 0.030) although this difference was not significant ($t = 2.19$, $p = 0.07$). Using Hill's (1972) formulae for estimating the sampling variance for a realized heritability estimate, we find that $V(h^2) = 0.021$ or roughly twice the sampling variance of the regression coefficient. Despite the added variance due to drift, the overall estimate of heritability is significantly greater than zero.

The different size-selective harvest regimes to which the stocks were subjected had dramatic effects not only on juvenile growth but also on the characteristics of other life stages. By generation 4, large-size harvested populations produced only half as many eggs as small-size harvested fish, and their eggs were 22% smaller in volume (Table 1). Larval length at hatching was 7% smaller in large-size harvested fish. Larval growth rates declined significantly by about 25% in the large-size harvested lines (Fig. 3). In addition, the physiology of growth changed dramatically among the stocks. Large-size harvested populations evolved lower food consumption rates and lower gross growth efficiencies than small-size harvested populations (Table 1).

Implications

The results of our harvest experiment clearly demonstrate that substantial genetic changes in population productivity, driven by changes in the growth rate and physiology of individuals within populations, can occur over a short period of time in response to size-selective harvest regimes. Population yield declined primarily because of selection of genotypes that had lower food consumption rates and lower growth efficiencies (Table 1).

The rapidity of response was not due to unusually high heritability. Our heritability estimate of 0.198 is nearly equal to the mean (0.2) for quantitative characters across many organisms, including fishes (Roff 1997), although it is somewhat higher than the mean for life history traits (0.11, Roff 1997).

Although the two-fold change in yield among the populations is high, it likely represents an underestimate of the changes in overall population productivity. This is because we standardized "recruitment" to each population at about 1,100 juvenile fish per generation (by removing excess fish at the end of the larval stage) in order to prevent changes in density from confounding the results. Had we allowed recruitment to be proportional to juvenile production, the differences in yield among lines may have been even greater. The small-size harvested lines produced twice the number of eggs, their eggs were bigger, their larvae were bigger, and their larvae survived better, than large-size harvested fish (Table 1). Hence recruitment success was far greater in the small-size harvested populations. Moreover, the increased larval stage durations that would result from the slower growth of larvae would increase overall larval mortality rates in nature (Houde 1987). Although some of these changes in early life history traits may be phenotypic correlates of female size (e.g., egg size), rather than genetic changes, they nonetheless represent real differences in stock productivity that would have cascading effects on the sustainability of yield.

We acknowledge that the response we would expect to see in actual fisheries in nature will not be as rapid as occurred in our experiment. However, we believe that the suite of physiological responses we observed will also occur in the wild harvested species, albeit at a slower rate. The reasons are as follows.

First, since our estimate of heritability is not unusually high, the results of this experiment should be readily applicable to many other species. Second, the existence of CnGV in growth in numerous species proves that production traits of fishes, such as growth, are capable of evolving in the wild, despite the potential for gene flow across marine populations. Third, although the overall rate of harvest and its size-selectivity in our experiment were abnormally high, fisheries also impose rates of mortality that greatly exceed natural mortality and they represent an age specific trajectory of mortality that differs greatly from that under which stocks evolved prior to fishing. Fourth, declines in size at age as fishing mortality increases have been identified in numerous fisheries (e.g., Ricker 1981 ; Rochet 2000; Haugen and Vollestad 2001; Sinclair et al. 2002). These changes are the opposite of those predicted by density-dependent fisheries theory and therefore almost certainly represent genetic change. Fifth, there is compelling evidence from recent studies of introductions of a variety of species that life history traits in general are capable of rapid evolution in the wild (Reznick et al. 1990; Quinn et al. 2001; Hendry 2001; Haugen and Vollestad 2001). Given countless examples of rapid evolution in response to human-induced selection pressures in many organisms (Palumbi 2001), there appears to be no scientifically-based rationale for arguing that fish stocks represent an exception to the principals of evolution. Given the potential for declines in yield that may be difficult to reverse, failure to consider the evolution consequences of harvest selection on population productivity and yield is inconsistent with a precautionary approach to fisheries management.

Size-selective harvesting in the manner it has historically been pursued appears unsustainable on evolutionary grounds. At each generation, the fishery exerts selection pressure forcing the evolution of life histories that are not only far different from the natural condition but are also substantially less productive. These changes occur in relatively short periods of time and harvest strategies need to be modified to account for them. It is conceivable that in some special cases where the ages of harvested individuals can be managed effectively, that fisheries might intentionally select for increased body size through the imposition of maximum size limits. This approach is not likely to be broadly applicable, however, because increases in mortality alone will select for earlier age at maturity. A simple conservative approach that may be successful is the establishment of no-take reserves or marine protected areas (MPA's). Carefully designed and situated MPA's may provide protection for the fast-growing, late-maturing genotypes that would otherwise be lost to fishing.

Our results show that evolution in response to harvest will likely result in populations with a suite of undesirable characteristics. How long will it take for stocks to return to their original state if fishing ceases? If the changes are purely ecological phenomena then population productivity may be restored within a generation by simply decreasing fishing mortality. However, if these traits are adaptive responses to size-selective fishing, the return to 'normal' life histories is likely to take much longer. Several modeling studies with different sets of assumptions have all indicated that natural selection on life histories is much weaker than selection imposed by fishing. Consequently, the time required for life histories to return to an unfished state will likely be much longer than the time required to produce them. We are now testing this hypothesis by continuing our harvest experiment over additional generations during which all populations experience non-selective mortality.

Acknowledgements

We thank the New York Sea Grant Institute and the U.S. National Science Foundation for financial support. We thank the many members of the Conover Lab for many hours of labor in maintaining the captive stocks over the 4-year period of the experiment.

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Figure 1. Response to selection and estimation of heritability. A. Mean length at 190 days for each experimental line. Circles, triangles, and squares denote small-size-harvested, random-size-harvested, and large-size-harvested lines, respectively. Closed and open marks represent replicates of each treatment. Generation axis has been dithered by ± 0.1 for each replicate to improve clarity of presentation. Error bars show ± 1 SE based on differences between phase means.

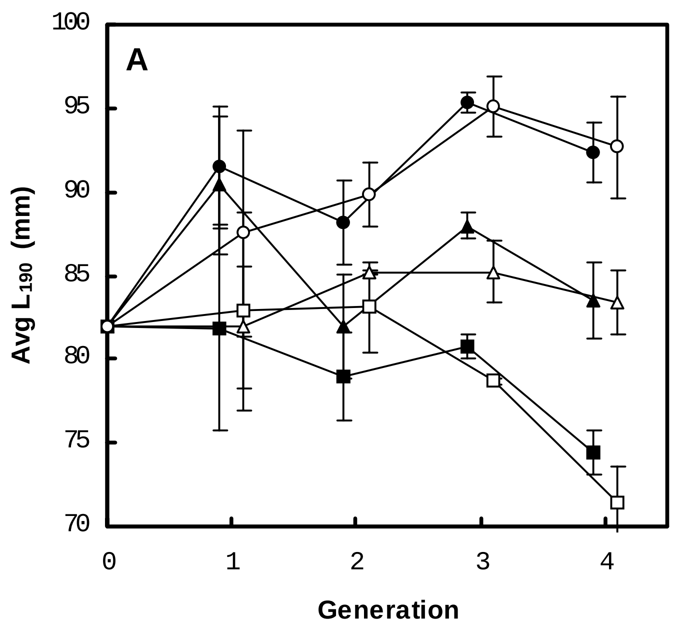

Figure 2. Harvested biomass in generation 4 versus direction of selection. Bars indicate total mass harvested averaged over the phases and lines. Error bars are ±1 S.E. based on the variability among lines and phases. L = large-size harvested, R = randomly harvested, and S = small size harvested lines.

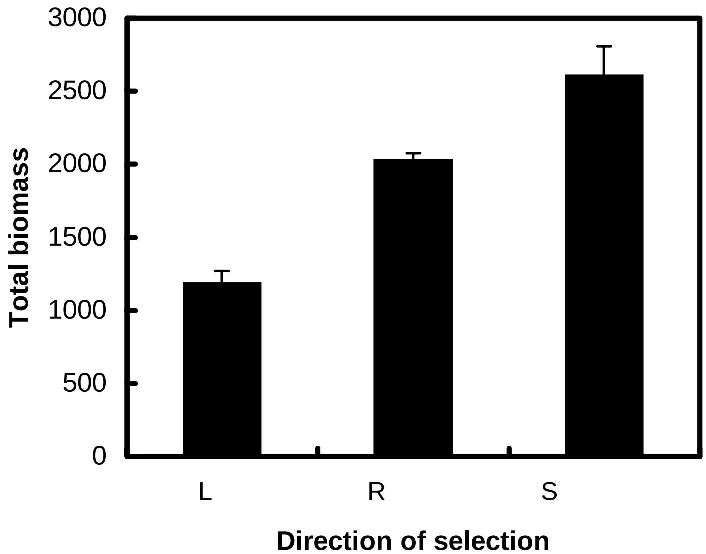

Fig. 3. Correlation among larval growth rates and length on day L_{190} across the six populations is highly significant ($r = 0.88$, $p < 0.01$) after removal of common environmental effects for each.

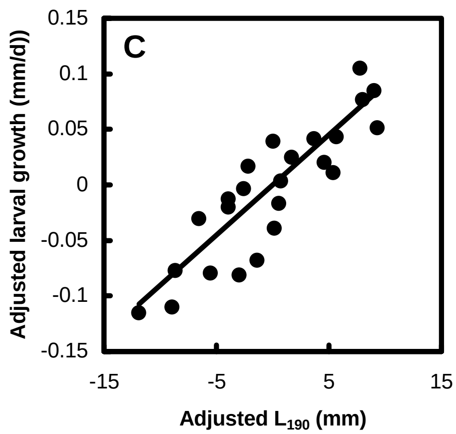

Table 1. Variation in physiological and early life history traits among the three size-selected harvested populations. Each datum represents the mean of trials across replicate lines of each treatment. Number in () is 1 s.e.

Trait	Small-size harvested	Random-size harvested	Large-size harvested
Food Consumption* (mg/day)	6.48 (.14)	5.73 (.14)	5.74 (.14)
Gross Growth* Efficiency (%)	34.33 (1.32)	28.36 (.816)	21.85 (1.01)
Critical Swimming Speed (cm/sec)	25.59 (1.06)	25.47 (1.04)	27.65 (1.26)
Larval Size at Hatch* (mm)	5.21 (.02)	5.00 (.02)	4.87 (.02)
Egg Volume (mm^3)*	.728 (.0057)	.658 (.0047)	.598 (.005)
Larval Survival* (% surviving ten days post-hatch)	43.17 (8.88)	33.00 (7.07)	13.00 (6.04)

* - denotes significant population ($p < .05$) differences

Appendix D

Canadian Code of Conduct for Responsible Fishing Operations

CONSENSUS CODE 1998

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INTRODUCTION

The Canadian fishing industry is committed to the achievement of sustainability in marine and freshwater fisheries. The industry has therefore developed this Code of Conduct for Responsible Fishing Operations as an essential step in pursuit of this objective.

The Canadian Code of Conduct for Responsible Fishing Operations outlines general principles and guidelines for all commercial fishing operations that take place in Canadian waters. Implementation of the Code will contribute directly to the conservation of stocks and the protection of the aquatic environment for present and future generations of Canadians.

Bearing in mind that Canada played a leading role in the development of the U.N. Food and Agriculture Organization (FAO) Code of Conduct for Responsible Fisheries, this Canadian Code of Conduct is consistent with, and in no way diminishes, the FAO Code.

The Canadian Code of Conduct is based on the following fundamental points of agreement:

1. That the Code of Conduct for Responsible Fishing Operations is applicable for all participants in commercial fishing operations in Canadian waters;

2. That there are four distinct fishing regions in Canada: Atlantic, Pacific, Arctic and inland fisheries, and each region will require specific mechanisms and regulations to address the unique problems and needs of their fisheries;

3. That nothing in this Code will serve to justify or impose any allocation or sharing of freshwater or marine resources;

4. That Conservation Harvesting Plans or Fisheries Management Plans should incorporate the Code of Conduct.

In developing this Code, Canadian commercial fish harvesters expect that other users of marine and freshwater resources will develop their own codes of conduct within the FAO framework to contribute to the sustainability of those resources. It is also expected that Canadian fisheries regulatory agencies will take appropriate steps to bring their fisheries management policies and practices into line with this Code and will make themselves accountable to the resources users in this regard.

The Code of Conduct for Responsible Fishing Operations articulated by Canadian fish harvesters has at its core a philosophy of responsible fishing. Based on this philosophy, fish harvesters who have ratified this Code will pursue the following principles:

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PRINCIPLES

Principle #1
Fish harvesters will take appropriate measures to ensure fisheries are harvested and managed responsibly to safeguard sustainable use of Canada's freshwater and marine resources and their habitats for present and future generations of Canadians.

For the purposes of this Code, sustainability is understood to mean the harvesting of a stock in such a way, and at a rate, that does not threaten the health of the stock, or inhibit its recovery if it has previously been in decline, thereby maintaining its potential to meet the needs and aspirations of present and future generations of fish harvesters.

Principle #2
Taking into account the economic importance of the fisheries to industry participants and their communities, fish harvesters will take appropriate measures to pursue the ecological sustainability of Canadian fisheries.

Principle #3
Fish harvesters will acknowledge that conservation and sustainable use of freshwater and marine resources is a shared responsibility, and requires a spirit of cooperation, among all industry participants and the appropriate regulatory authorities.

Principle #4
Fish harvesters will address problems of fisheries in Canada, adopting specific mechanisms and regulations as required.

Principle #5
Fish harvesters will work to balance the level of fishing effort with the sustainable supply of fisheries' resources to ensure responsible management and responsible professional harvesting.

Principle #6
To the extent practical, fish harvesters will minimize unintended bycatch and reduce waste and adverse impacts on the freshwater and marine ecosystems and habitats to ensure healthy stocks.

Principle #7
Fish harvesters will develop, maintain and promote public awareness and understanding of the issues surrounding responsible fishing and the measures taken by fishers to conserve stocks and protect the environment.

Principle #8
Fish harvesters will promote the recognition of their specialized knowledge gained through experience, and the integration of this knowledge within scientific analyses and fisheries management policies and regulations.

Principle #9
Fish harvesters will conduct harvesting operations in accordance with Canadian fisheries' laws and regulations; international laws, regulations, conventions, declarations and protocols adopted by Canada; and harvesting plans adopted by each fishery.

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GUIDELINES

Guideline #1.1
Apply sustainable fishing principles and sustainable fisheries development to all aspects of fish harvesting and management of fisheries.

Guideline #1.2
Practice environmentally sound waste management in all aspects of harvesting operations.

Guideline #1.3
Optimize energy consumption in fishing operations where possible.

Guideline #1.4
Adopt practices that would minimize emissions of dangerous substances arising from harvesting operations to meet national standards.

Guideline #1.5
Establish fisheries policies in full consultation with management and other regulatory agencies to ensure conservation of fish resources and protection of the environment.

Guideline #1.6
Recognize and support efforts to balance the economic needs of fish harvesters and industry with the short- and long-term needs of resource sustainability.

Guideline #1.7
Work in full consultation with management, other regulatory agencies, and all interested groups to consider the possible introduction of marine protected areas.

Guideline #2.1
Develop protocols (including, when practical and appropriate, the use of selective fishing gears and practices) regarding the catch of non-targeted resources which jeopardize the health of the stocks.

Guideline #2.2
Use only gear authorized for use in a particular fishery.

Guideline #2.3
Ensure fishing activities are not conducted in a fashion that would endanger fish stocks or the environment.

Guideline #2.4
Conduct, in consultation with relevant sectors, research to assess fishing gears, and promote and utilize new fishing gears and practices which are consistent with sustainable fishing practices.

Guideline #2.5
Assist, initiate, and participate in research and assessment initiatives aimed at resource and environmental protection.

Guideline #2.6
Employ fishing practices that minimize the risk of gear loss.

Guideline #2.7
Establish jointly with regulatory agencies protocols for the marking, retrieving and reporting of lost gear.

Guideline #2.8
Make every reasonable effort to retrieve lost fishing gear, reporting all lost gear.

Guideline #3.1
In conjunction with the relevant regulatory agencies, establish and comply with guidelines for vessel maintenance and operation that ensure and safeguard a healthy environment for crew members.

Guideline #3.2
Mark vessels and gear in accordance with systems adopted by Canada's regulatory agencies so that vessels are easily identified.

Guideline #3.3
Avoid interfering with fisheries operations being carried out by other vessels.

Guideline #3.4
Maintain the quality of the catch.

Guideline #4.1
Where appropriate, establish, in consultation with relevant regulatory agencies and industry groups, effective monitoring systems to monitor and evaluate the adherence to sustainable development principles and practices.

Guideline #5.1
Establish and maintain a spirit of co-operation with those involved in fisheries operations, management, science, and technology.

Guideline #5.2
Co-operate with management and science to develop policy and action plans for sustainable fishing operations.

Guideline #5.3
Assist with the establishment of effective mechanisms to ensure consultation and active participation of fish harvesters in the planning, development, conservation, and management of Canadian fisheries, recognizing that full co-operation among gear sectors and species-specific fisheries will facilitate conservation and sustainable use of freshwater and marine resources.

Guideline #5.4
Acknowledge and embrace the interdependence of harvesting operations and fisheries management

Guideline #5.5
Cooperate with fisheries management to integrate and balance the experience, expertise, and acquired knowledge of practicing professional fish harvesters with the best scientific research available.

Guideline #5.6
Cooperate with industry and other fish harvesters to identify issues related to protection of the resource and the environment.

Guideline #5.7
Cooperate with appropriate regulatory authorities to establish sound waste management policies and procedures.

Guideline #5.8
Cooperate with appropriate regulatory agencies to investigate ways and methods to optimize fuel consumption and other energy savings and to establish energy conservation policies and procedures.

Guideline #5.9
Cooperate with fisheries management to address problems experienced by individual Canadian fisheries and where there is a shared or overlapping jurisdiction, work cooperatively towards a fair and agreed basis for conducting individual fisheries.

Guideline #6.1
Assist in the development of and participate in education and training programs that emphasize responsible fishing and sustainable development practices.

Guideline #6.2
Promote the development of education and training programs designed to enhance the skills of responsible fishing adapted to specific fisheries.

Guideline #6.3
Participate in the planning and implementation of research and assessment initiatives aimed at protecting the biodiversity of the freshwater and marine ecosystems and their habitats.

Guideline #6.4
Collect and provide research and assessment data related to fishing activities.

Guideline #6.5
Support research initiatives aimed at minimizing adverse impacts to the resource and the environment.

Guideline #7.1
Assist in the promotion of public awareness and understanding of the issues and benefits surrounding responsible fishing, the industry's involvement in sustainable development initiatives, and measures taken to conserve fish stocks and protect the aquatic environment.

Guideline #7.2
Assist in the dissemination of information to the general public and to fish harvesters and

their organizations regarding conservation principles, conservation measures taken by fish harvesters, and rules and regulations formulated in consultation with management.

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ANNEX 1 Plan for Governance and Ratification of the Canadian Code of Conduct for Responsible Fishing Operations

1. OPERATIONAL CONSIDERATIONS

This approach is based on the following considerations:

1. The Code will, of necessity, be a "living document" subject to continuing revision and elaboration.
2. The Code will be managed by a newly created Industry Board reflecting the character and nature of Canada's fishing industry.
3. Implementation of the Code will require the services of a Secretariat to support the full and effective participation of industry.
4. The new governance body for the Code will be structured to take account of the limited financial resources available from government and industry.

1.1 Proposed Roles and Responsibilities for the Code Board

Following the National Fishing Industry Workshop the Code Steering Committee will be replaced by a formally constituted National Board with the following responsibilities:

1. oversee the ratification of the Code, ensuring that all industry organizations are included in the process and that the process is fully transparent;
2. conduct annual meetings to address proposals for changes to the Code text, on the understanding that no such changes will be put into effect without ratification by industry according to the guidelines for ratification set out below;
3. oversee ongoing activities in support of the Code and its implementation, including communications and promotion;
4. represent the Code in dealings with Canadian government agencies and international bodies;
5. direct and oversee the activities of the Secretariat to support the Code.

6. at the end of three years, conduct full consultations with industry to evaluate the roles and functioning of the Board and to consider appropriate changes in the Board's mandate, structure and operations. The question of the continuing need for the Board should be assessed at this time.

1.2 Proposed Structure of the Board

	Inshore - Midshore	Offshore (>100')	Global	Total	Umbrella Group
Arctic			1	1	
Freshwater			2	2	
Aboriginal Commercial Fish harvesters			1	1	To be determined
Pacific Coast			3	3	CFIC
Atlantic Coast	4	1	1	6	CCPFH/FCC/midshore fleets
Total	4	1	8	13	

Board members would be selected through the following steps:

- The Arctic marine fisheries representatives at the National Industry Workshop, in consultation with other groups, would together pick one Board Member.

- The Ontario Commercial Fishermen's Association would select one freshwater representative, and the other freshwater representative from the western provinces and the Territories would be selected through the elected Advisory Committee to the Freshwater Fish Marketing Corporation.

- For the Pacific region, the Commercial Fishing Industry Council of British Columbia (CFIC), in consultation with the B.C. affiliates of Canadian Council of Professional Fish Harvesters (CCPFH), would select three Board Members.

- For the Atlantic fisheries, the CCPFH would select four representatives from the inshore (<65') sector, the Fisheries Council of Canada (FCC) would select one representative for the offshore (>100'), and representatives of midshore mobile gear fleets (45' to 100') that aren't affiliated with either body would select one Board member.

It is further proposed that individual Board members would serve for a maximum of three years.

1.3 The Code Secretariat

Given the limited financial resources to support the implementation of the Code, and the clear agreement that the Code should not involve extra costs to the fishing industry, it is proposed that the DFO will continue to provide Secretariat support.

Following the National Industry Workshop the Secretariat will operate under the direction of the new Board.

2. RATIFICATION OF THE CODE

It is proposed that the ratification of the Code will involve the following steps:

1. the National Fishing Industry Workshop will agree on a Code text and proposals for governance;

2. the new Code Board will send out the Code text and governance proposals to all organizations representing fish harvesters for discussion and ratification according to the policies and procedures of each organization;

3. these organizations will either ratify or reject the Code and the governance proposals;

4. within six months after the National Fishing Industry Workshop, the newly constituted Board will communicate to appropriate fisheries Ministers the names of the industry organizations that have ratified the Code;

5. organizations that ratify the Code will be expected to promote adherence to the Code by their members in their harvesting practices, and also to cooperate with the appropriate government regulatory agencies to adjust their Conservation Harvesting Plans to reflect the provisions of the Code.

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Appendix E

DFO - WAVES Output

http://inter01.dfo-mpo.gc.ca/waves2/search.html?__LANG=en

catno	title	author	publ	year	abstract
279074	Changes in the North Sea fish community : evidence of indirect effects of fishing?	Daan, N.; Gislason, H.; Pope, J.; Rice, J.	Copenhagen : The Committee, 2003	2003	We investigate changes in the fish community with particular reference to possible indirect effects of fishing, mediated through the ecosystem. In the past, long-term changes in the slope of size spectra of research vessel catches have been related to changes in fishing effort, but such changes may simply reflect the cumulative effect of direct effects of fishing through selective removal of large individuals. If there is resilience in a fish community towards fishing, we may expect increases in specific components, for instance as a consequence of predation and/or competition. We show on the basis of three long-term trawl surveys that abundance of small fish (all species) as well as abundance of species with a low maximum length (demersal species only) have steadily and significantly increased in absolute numbers over large parts of the North Sea during the last 30 years. Taking average fishing mortality of assessed commercial species as an index of exploitation rate of the fish community, it appears that fishing effort reached its maximum in the mid-1980s and has declined slightly since. If the observed changes are caused by indirect effects of fishing, there must be a considerable delay in response time, because the observed changes proceed up to recent years.
263314	Selective (salmon) fisheries program : final report		Vancouver, BC : Pacific Region, Dept. of Fisheries and Oceans Canada, 2002	2002	
263446	Salmon sense : a training series for responsible fishing [videorecording]		Vancouver, BC : Fisheries and Oceans Canada, 2002	2002	This video contains eight modules: 1) Overview; 2) Salmon Species Identification; 3) Handling Live Salmon; 4) Seclective Troll Fishing; 5) Selective Gillnet Fishing; 6) Selective Seine Fishing; 7) B.C. Salmon Quest for Quality; 8) First Nations Selective Fishing. this series is designed for use in all fishing sectors; First Nations. Recreational and Commercial. It focuses on selective fishing as a management tool for conservation.
273581	Fisheries-induced changes in age and size at maturation and understanding the potential for selection-induced stock collapse	Ernande, B.; Dieckmann, U.; Heino, M.	Copenhagen : The Council, 2002	2002	Fishing is very likely to create selective pressurs inducing adaptive changes in the life histories of harvested stocks. Using field data and adequate statistical methods, such alterations can be demonstrated. However, in order to understand underlying causes and to evaluate alternative management practices, past selective pressures must be quantified and predictions of future evolutionary changes are needed. In this respect, modelling the ecological and evolutionary dynamics of exploited stocks is a critical challenge. To illustrate this point, we studied the evolution of age and size at maturation induced by fishing using adaptive dynamics theory - a framework that allows modelling long-term evolution of quantitative traits under density- and frequency-dependent selection. Specifically, we investigated the evolutionary implications of alternative management policies. As a novel contribution to the discussion of fisheries-induced adaptive change, we showed that frequency-dependent selection, arising from fishing mortality under some particular management policies, can not only reduce the age and size at maturation and thus stock biomass, but can ultimately even induce the extinction of entire stocks. The potential for such phenomena of 'evolutionary suicide' is overloo
273589	Fisheries-induced long-term effects on age-at-maturation in mixed fisheries	Gardmark, A.	Copenhagen : The Council, 2002	2002	Theoretical and experimental studies show that fishing can change the genetic composition of exploited species. In particular, selective fishing of older and larger individuals can cause maturation at an earlier age and smaller size. These predictions, however, are all based on single-species considerations. Our recent studies show that in the presence of species-interactions, the potential evolutionary response to fishing in ambiguous: fishing can cause either earlier or later maturation depending on the type of interaction and its strength relative to the fishing pressure. Moreover, interactions between the target species and other species provide a mechanism whereby fisheries can induce long-term genetic effects also in unexploited and non-target species. Here, I review our findings and discuss their implications for the long-term genetic effects of mixed fisheries on age-at-maturation.
273582	Darwinian fishery management : rapid evolution of somatic growth and yield in experimentally harvested marine fish populations	Conover, D.A.; Munch, S.B.; Walsh, M.	Copenhagen : The Council, 2002	2002	Fishery management regimes encourage selective harvest of the larger and faster growing members of a population, yet ignore the potential for evolutionary change in harvestable biomass and other traits. To empirically model this process, we subjected six replicate populations of a mrine fish (Menidia menidia) to large, small, or random size-selective harvest of adults over five generations. Harvested biomass evolved rapidly in directions counter to the size-dependent force of fishing mortality. Large-size-harvested populations initially produced the largest catch but quickly evolved a lower exploitable biomass than controls. Small-size-harvested populations did the reverse. By generation four, the yield from small-size-harvested lines was two-fold higher than in large-size-harvested lines. These shifts were caused by selection of genotypes with slower or faster rates of growth, not changes in survival. Change in growth among lines was positively correlated with change in intrinsic rates of energy acquisition: i.e., faster growing lines evolved higher food consumptions rates. Our results illustrate the need to account for evolutionary dynamics in devising plans for long-term sustainable harvests.
275927	Effects of variable and size-selective gill-net fishing on life-history evolution in grayling	Haugen, T.O.; Vollestad, L.A.	Copenhagen : The Council, 2002	2002	This study investigates effects of variation in fishing mortality on contemporary life-history trait evolution within and among five grayling populaitons with common ancestors. We had access to synchronic life-history data from populations that have been segregated for 44-88 years and allochronic data spanning 95 years. Estimated evolution and divergence rates were high copared with other studies performed on the same temporal scale. Because adult survival was negatively correlated with fishing intensity the observed divergence in adult traits was probably caused by differential mortalities induced by variation in fishing intensity. A similar divergence pattern was observed among coexisting trout Salmo trutta populations, suggesting convergent evolution. The allochronic data revealed that eight generations of size-selective gill net fishing rsulted in a reduction in age and length at maturity with time. After relaxing the fishing, age and length at maturity increased. Deviations from the recent maturations-growth reaction norm suggested that the change in maturation pattern should not be attributed to phenotypic plasticity. Lie-table simulations supported that a decrease in age and size at maturity is ultimately favoured with increasing intensity of a size-selective gill net fishery.
252358	A policy for selective fishing in Canada's Pacific fisheries		[Vancouver, BC : Fisheries and Oceans Canada], 2001	2001	This document, the seventh in a series that began in October 1998 with A New Direction for Canada's Pacific Salmon Fisheries, sets out selective fishing policy and an implementation framework for Canada's First Nations, recreational and commercial fisheries in the Pacific Region. It builds on the May 1999 discussion document, Selective Fishing in Canada's Pacific Fisheries, and incorporates the outcome of discussions with, and comments from, First Nations, commercial and recreational fishers and other stakeholders in the Pacific fisheries that resulted from that release.
254181	Design and testing of the Gisgagaas Canyon fishwheels and the design of new baskets for the Shedin fishwheel	Mikkelsen, J.; Muldon, C.	Hazelton, BC : Gitksan Watershed Authority, 2001	2001	
269662	Perspectives on selective fishing in the Pacific region, 1998-2001	Wood, A.; Fearon, M.	[Vancouver, BC] : Simon Fraser University Continuing Studies in Sciences for Fisheries and Oceans Canada, c2001	2001	This report reflects the work of all those who have contributed to the Selective Fishing Program over the past three years, in an effort to conserve certain species of fish, while at the same time supporting the economic opportunities provided by the fishing industry in British Columbia. The report is divided into three sections: Part 1) Three years of selective fishing; Part 2) Selective Fishing Community Workshops, winter 2000-2001; Part 3) Selective fishing direction, tools and implementation : summary report of the Multistakeholder steering committee, January 2001
254195	Development of a power assisted fishwheel and a bubble lead for use on the lower Fraser River	Mikkelsen, J.; Ned, M.	Abbotsford, BC : Sumas First Nation, 2001	2001	
269565	Selective fishing newsletter		[Vancouver, BC] : Fisheries and Oceans Canada, 2001-2002	)01; 2002	
270416	Technical evaluation of selective fishing gear & methods		[Ottawa] : Dept. of Fisheries and Oceans, 2000	2000	Contains information from an interim report which contains summaries of an inventory of existing literature and reports on selective fishing (gear and methods) studies for salmon conducted in Alaska, British Columbia and Washington from 1995-2000. It was conducted as part of a technical evaluation of the selective Fishing Program by Fisheries and Oceans Canada. The charts are broken down by gear type, seine, gillnet, commercial troll, recreational, fish wheels, fish traps and beach seines. The summaries include brief descriptions of objectives, selective fishing gear and methods tested, results, conclusions and recommendations, if any
244244	Fifty years of selectivity in the Fraser River gillnet fishery	Drouin, M.; Regier, A.	[Surrey, B.C.] : Pacific Employment and Environmental Initiatives Cooperative Association, 2000.	2000	Fraser River gillnetters are facing a new regime of fishing restrictions and fishing practices. Fisheries and Oceans Canada announced a \new direction

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catno	title	author	publ	year	abstract
254198	Design, construction, and testing of the Tsimshian fishtrap on the lower Skeena River	Mikkelsen, J.; Smith, .	Prince Rupert, BC : Tsimshia Tribal Council, 2000	2000	
243234	Fishing salmon selectively in British Columbia : report of the third Selective Fisheries Multi-Stakeholder Workshop, November 22-24, 1999, Richmond, B.C.		Vancouver, BC : Fisheries and Oceans Canada; Fisheries Renewal BC, 2000	2000	
283441	Selective fishing in the Canadian commercial salmon fishery : an analysis of the selectivity of the gillnet sector	Hosegood, J.A.	2000	2000	The coho crisis of 1998 prompted the adoption of a fleet wide selective fishing strategy aimed at protecting coho salmon that originated from upper Thompson and Skeena rivers. This research focuses on the effects of the gillnet fleet
284497	A comparison of the standard recovery box and a re-designed laminar flow box in the recovery of coho salmon (Oncorhynchus kisutch) caught with commercial seine gear : mortality rates and swimming performance	Berry, M.; Gallaugher, P.; Farrell, A.P.; Buchanan, S.; Pike, D.	2000?	2000	Simon Fraser University, Fisheries and Oceans Canada, and the commercial fishing industry have been working on an innovative research project examining post-release mortality rates as they relate to the current selective fishery catch and release policy
235880	Selective fishing in Canada's Pacific fisheries : a new direction : the third in a series of papers from Fisheries and Oceans Canada		[Vancouver, B.C. : Fisheries and Oceans Canada], 1999	1999	This paper sets out the policy framework for selective fishing in Canada's Pacific fisheries. It will serve to provide a basis for discussion among First Nations and stakeholders in the Pacific fisheries between May and December of 1999. At that time, all comments and advice will be considered by Fisheries and Oceans Canada to develop a final policy paper on selective fisheries. This paper also provides an overview of global and Canadian activities related to responsible fishing and provides the context for a selective fishing policy framework. Objectives and strategies for selective fishing in all fisheries, and specifically the salmon fishery, as well as next steps for selective fishing, are presented
252199	Selective salmon fishing in B.C. [videorecording] : beginnings of change		Vancouver, BC : Fisheries and Oceans Canada, 1999	1999	This video highlights an experiment done in Alberni Inlet in 1998. University and DFO scientists got together with commercial gill net fishers to test ways of increasing the survival of coho salmon by using different types of net mesh and brailing instead of ramping as a method of hauling fish onto the boat decks where they are sorted. Approximately 7,000 coho were tagged in this study and blood & tissue samples were taken for DNA analysis etc. Two new designs of brailer were tested as well as selectivity grids
285656	Fishing salmon selectively : commercial sector applications for selective fisheries proposals, 1999 : a comprehensive program for the testing and evaluation of selective fishing methods		Vancouver, BC : The Committee, 1999	1999	
252198	Selective salmon fishing in BC [videorecording] : a 1998 overview		Vancouver, BC : Fisheries and Oceans Canada, 1999	1999	
252197	Restoring respect : aboriginal selective fishing in B.C. [videorecording]		Vancouver, BC : Fisheries and Oceans Canada, 1999	1999	
325526	Wheels, weirs, traps & nets : selective fishing in BC	Parfitt, B.	[S.l.] : BC Aboriginal Fisheries Commission, [1999?]	1999	
285654	Fishing salmon selectively : a comprehensive program for the testing and evaluation of selective fishing methods		Vancouver, BC : The Committee, 1998	1998	
228084	Responsible fishing techniques, practices and training in Canada 1998 = Techniques, pratiques et formation en peche responsable au Canada en 1998		Ottawa : The Dept. = Le Ministere, 1998	1998	This document provides a summary of the key elements of responsible fishing efforts carried out in Canada in recent years. It includes a brief description and drawings/photographs of selective fishing techniques and gears, responsible fishing practices and industrial/high scholl training projects.
234222	Guidelines for conducting experiments on the selectivity of BC salmon gillnets		Vancouver, B.C. : Dept. of Fisheries and Oceans, Responsible Fishing Operations, 1998	1998	Historically, gillnets have been viewed positively because the gear is efficient and size selective. However, more recently the use of gillnets to fish salmon has come under some criticism. This criticism arises because of the incidences of by-catch (e.g. Coho salmon and other species). Fishers committed to sustainable use of the resource want to conduct ongoing experimental trials to assess the selectivity of various mesh sizes and riggings, etc. and the effect selectivity has on the sustainability of fish stocks. The main objective of this work is to find ways of reducing the by-catch of Coho salmon and other non-targeted species and to reduce the number of small fish killed in fishing operations
282105	Selective salmon fishing in BC : beginnings of change [videorecording]		Nanaimo, BC : Pacific Region, Selective Fisheries Project Authority, Fisheries and Oceans Canada, c1998	1998	
276271	Evaluation of selective salmon fisheries in the lower Fraser River		[Vancouver, BC] : J.O. Thomas & Associates, 1997	1997	Oncorhynchus keta
196986	Declining weight-at-age in northern cod and the potential importance of the early-years and size-selective fishing mortality	Krohn, M.; Kerr, S.	[Dartmouth, N.S.] : Northwest Atlantic Fisheries Organization, 1996	1996	Weight-at-age of northern cod has been declining since 1979 for all age-classes, while the greatest reduction in size-specific growth has been before age 3. To what extent could the declining weight-at-age 3 be responsible for smaller weights in older age-classes, and to what extent are size-specific growth rates of the older age-classes declining? The among year variability in weight-at-age 3 explained 54% of the variability in weight-at-age of older age-classes of the same cohorts, and differences in wegith-at-age among cohorts suggest that cohorts that are small early in life tend to stay small. According to our simulations, over 50% of the decline in weight-at-age of 4 to 8 year-olds can be attributed to a decline in weight-at-age 3. These results suggest that size in early years greatly influences future production but also that weights-at-age are lower than one would expect purely from small sizes at age 3, and therefore that the environment for growth in the older age-classes has worsened. Because cod are recruited to the fishery at age 3, it is possible that some of the decline in weight-at-age 3 may not be due to reduced growth rate, but may be a result of size-selective fishing mortality.
198738	Bioeconomic and biological effects of size selective harvesting of North-East Arctic cod	Andreasson, S.; Flaaten, O.	Copenhagen : The Committee, 1996	1996	The aim of this paper is to study the bioeconomic effects on harvest rates, resource rent, vessel profitability, employment etc. of using the Sort-X selectivity in bottom trawl fishing for North East Arctic cod. For comparison, the bioeconomic results of conventional trawl selectivity and coastal fishing will also be derived. Three different types of fisheries, foreign trawl, Norwegian trawl and Norwegian coastal fisheries are calculated in the analysis.

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catno	title	author	publ	year	abstract
234065	Potential effects of selective fishing on stock composition estimates from the mixed-stock model : application of a high-dimension selective fisheries model	Lawson, P.W.; Comstock, R.M.	Portland : Oregon Dept. of Fish and Wildlife, 1995	1995	The objective of this report is to summaraize the available information of the walleye population and fishery in John Day Reservoir and to outline alternatives for managing walleye based on that information and the Oregon Department of Fish and Wildlife management plan for warmwater game fish.
199782	Genetic diversity of marine fisheries resources : possible impacts of fishing	Smith, P.J.	Rome : FAO, 1994	1994	This report reviews the evidence for the genetic impact of fishing on marine fisheries resources. The most widely used method for measuring genetic diversity in natural populations has been protein electrophoresis; marine teleosts have levels of genetic diversity ranging from 0.0 to 18% and marine invertebrates from 0.4 to 32%. Genetic studies have shown that populations of marine species are less differentiated than freshwater species, experience temporal genetic changes, can be changed locally by pollution, and contain cryptic species. Genetic changes in populations occur through selection or drift. In natural populations fishing is a major source of mortality and is non random with respect to age and size of individuals. A common observation in heavily exploited teleost fisheries has been a decline in the age and/or size at sexual maturity. Size selective fishing would favour early maturity. However, growth rate in some fishes is density dependent and increases when the stock is reduced faster growth rates lead to a reduction in the age or size at onset of sexual maturity. Thus it is not possible to determine if the observed changes are genetic or compensatory in response to reduced stock density. Genetic drift is unlikely to be a major factor influencing levels of genetic diversity in many
235129	Report of the Expert Consultation on the Code of Conduct for Responsible Fishing - fishing operations, Sydney, British Columbia, Canada, 6-11 June 1994		Rome : FAO, 1994	1994	The report of the Consultation reviews the decisions taken by the FAO Committee on Fisheries and the request of the International Conference on Responsible Fishing, for FAO to elaborate a Code of Conduct for Responsible Fishing. The submissions of the Working Groups on Responsible Harvesting Methods, Selective Fishing Gear and Energy Optimization are summarized and recommended principles for inclusion.
178897	A study of selective fishing methods for the northern cod otter trawl fishery	Hickey, W.M.; Brothers, G.; Boulos, D.L.	St. John's, Nfld. : Dept. of Fisheries and Oceans, 1993	1993	Otter trawl selection for Atlantic cod was studied using both the trouser trawl and covered codend methods using two commercial trips in January and February, 1992. The codend selection studies investigated methods for reducing the catch of undersized cod using the trouser trawl method with 155mm diamond mesh, 135mm square mesh, 135mm diamond mesh with lastridge ropes hung at 85%. A rigid grid system (Sort-X) with 50mm bar spacings was tested using a variation of the covered codend method whereby a 43mm retainer was placed over the Sort-X system and a 43 mm codend used as a control. Selectivity parameters were estimated using the Select method for the trouser trawl experiments and a logistic regression procedure for the Sort-X system.
149265	Gear selectivity and the variation of yield	MacLennan, D.N.	[Copenhagen] : The Committee, 1993	1993	For constant fishing effort, the variation of yield is driven by largely unpredictable changes in the annual recruitment. Given the statistics of recruitment fluctuations, the yield variability depends on the level of effort and the selection parameters of the gear. This paper examines the significance of the latter effect, with particular reference to the shape of the selection ogive. An age-structured population model is used to develop the theory of yield variation. Gears are selective on fish length and the model includes stochastic length-at-age distributions. The model is applied to the North Sea haddock fishery using data from quarterly trawl surveys in 1991. The catch analysis is performed in quarterly steps to take account of the within-year growth of young fish. The results is performed in quarterly steps to take account of the within-year growth of young fish. The results show that the yield is least variable when the selection range is of the order of the 50% retention length. Thus \knife edge\" selection (zero selection range) is not the optimal harvest strategy when the objective is to minimise the yield variability."
148302	Gill-net selectivity of bass and white croaker using commercial catch data	Reis, E.G.; Pawson, M.G.	[Dartmouth , N.S.] : Northwest Atlantic Fisheries Organization, 1993	1993	The object of this study was to determine a method of estimating the selectivity of gill nets for which catch data are available for only a few mesh sizes. For bass, a model inferring retention from girth measurements of fish and mesh dimension, but which is independent of catch data, resulted in wide selectivity curves, which could not be used to predict mesh size which would most efficiently catch fish in a particular range. Methods utilising observed frequency distributions of the ratio between mesh perimeter and fish length or girth provided good fits between the catch and selectivity curves for the mesh sizes most used in a bass (Dicentrarchus labrax) fishery. For white croaker (Micropogonias furnieri), only one approach can be adequately applied to data obtained from only one mesh size which depends on the inference of selectivity from girth measurements. The results were unsatisfactory because the selectivity curve underestimates the catch, the catch curve does not fall within the probability of capture and because these methods ignore any fishing trial with mesh size that should theoretically be selective on certain length ranges. The role and usefulness of the selectivity models in the management of gill-net fisheries is discussed.
35213	Salmonid age at maturity	Meerburg, D.J.	Ottawa, Ont. : Dept. of Fisheries and Oceans, 1986	1986	Contents: 1) The scientific and management implications of age and size at sexual maturity in Atlantic salmon; 2) Age at first maturity in Atlantic salmon, Salmo salar: freshwater period influences and conflicts with smolting; 3) Ovarian development of Atlantic salmon smolts and age at first maturity; 4) Genetic factors in sexual maturity of cultured Atlantic salmon and adults reared in sea cages; 5) Parental influences and smolt size and sex ratio effects on sea age at first maturity of Atlantic salmon; 6) Optimum size and age at maturity in Pacific salmon and effects of size-selective fisheries; 7) Game theory and the evolution of Atlantic salmon age at maturation; 8) Growth and maturation patterns of Atlantic salmon in the Koksoak River, Ungava, Quebec; 9) Independence of sea age and river age in Atlantic salmon from Quebec North Shore rivers; 10) Age at first maturity of Atlantic salmon - influences of the marine environment; 11) Biological factors affecting age at maturity in Atlantic salmon; 12) Physical influences on age at maturity of Atlantic salmon : a synthesis of ideas and questions; 13) Assessment of selective fishing on the age at maturity in Atlantic salmon : a genetic perspective; 14) Implications of varying the sea-age at maturity of Atlantic salmon on yield to the fisheries.
108537	The selective action of gillnets on sockeye (Oncorhynchus nerka) and pink salmon (O. gorbuscha) stocks of the Skeena River system, British Columbia	Todd, I.S.P.		1969	
229123	The selective action of three gill net types on Columbia River chinook and coho salmon with recommendations for management	Bernhardt, C.; Stockley; C.E.; Mathews, S.B.	[Olympia, Wash.] : Dept. of Fisheries, Research Division, 1969	1969	
36908	The selective action of gillnets on Fraser River sockeye salmon	Peterson, A.E.	New Westminster, BC : The Commission, 1954	1954	The present report is a study of the selective action of linen gillnets for size, age class, sex ratio and numbers of sockeye salmon. The results from two years of experimental fishing with various mesh sizes of gillnet are presented. The selectivity of the commercial fishery is indicated. Variations in the size and sex ratio and possibly numbers of fish in the escapement are shown to be related to the indicated selectivity of the commercial gillnet fishery.