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BIOGRAPHICAL SUMMARY OF CONTRACTOR

Ian Bradbury is a postdoctoral fellow with the University of Windsor, Ontario. He has been working on questions of egg and larval dynamics, dispersal, and the evolution of cod for over a decade. Dr. Bradbury has published extensively on many aspects of cod life history from reproduction and fecundity to spatial genetic structure.

APPENDIX 1. Population trend data for each of the Atlantic Cod management units recognized by Fisheries and Oceans Canada

1. Cod in the Arctic Marine (0AB)

Stock Structure

There are very few population abundance data for cod in this region. Surveys of the offshore component date from 1999 to present and have produced low catches, but in general very little is known. Data on catches in the marine environment was provided by Tim Siferd (Fisheries and Oceans Canada) based on DFO and Northern Shrimp Research Foundation surveys. In addition to limited numbers of cod in the offshore, cod inhabit three meromictic lakes (Ogac, Qasigialiminiq and Tariujarusiq Lakes) on south Baffin Island. These lakes are characterized by physical barriers which restrict connectivity with the coastal environment (Hardie 2007) and result in high levels of genetic isolation from marine stocks and from each other (Hardie *et al.* 2006).

Life History

Very little life history information is available, Hardie (2007) suggests that for the lake populations, the size at 50% maturity is 36 cm (males) and 42 cm (females) and the age at 50% maturity varies between 3.9-5.0 yrs. Nothing is known regarding the life history of cod in the marine environment.

Abundance Trends

Although no regular assessment is conducted of these lakes, a mark-recapture study conducted in 1957-1962 and a recent estimate of population size (2003-2004) in Ogac Lake suggest little change with the estimated number of individuals at 500 >60 cm and 10,000 >25 cm (Hardie *et al.* 2006 and 2008). Little abundance data is available for marine cod in this region.

Threats

At present, the main threat to these lake populations is recreational fishing.

2. Northern Labrador (2GH)

Stock Structure

Templeman (1962) included cod off Newfoundland and Labrador in a single stock though acknowledging that future data may separate stocks in this region. The presence of a cline in growth rates from Labrador to Newfoundland (Fleming 1960) is consistent with isolation from Newfoundland populations.

Abundance Trends

There are very few population abundance data available for cod in this area. The available data are complicated by the fact that surveys prior to 1986 were line transect surveys (i.e., involving non-random sampling) whereas those conducted thereafter were stratified-random surveys and that the gear was changed in 1995 from the Engel trawl to a Campelen trawl. The data reported here are from Smedbol *et al.* (2002) and Worcester *et al.* (2009) and provided by D. Power, Fisheries and Oceans Canada (Figure A1). Based on an estimated age at maturity of 5.25 yr for the period 1947 to 1950 (Smedbol *et al.* 2002), northern Labrador cod have declined 85% over the past three generations, based on the available data (Table A1).

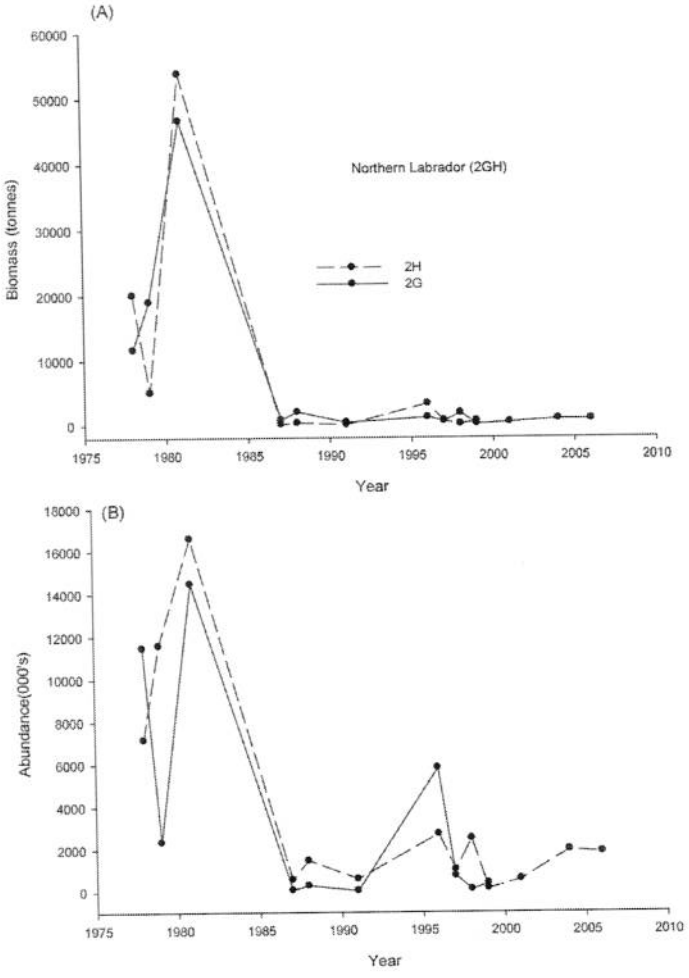

Figure A1. Temporal variation in biomass (A) and number of individuals (B) in the Labrador Stock (2GH). Data from DFO RV survey. See Worcester *et al.* 2009 for details.

Area of Occupancy

The survey coverage of 2GH is limited and as such that the calculation of area of occupancy is not considered to be valid.

Threats to Recovery

Commercial landings are minimal. Bycatch of cod in shrimp fisheries in 2G from 2004-2007 ranged between 241kg to 500kg annually (Orr 2008).

3. Northeast Newfoundland Shelf, or "Northern" Cod (2J3KL)

Stock Structure

Templeman (1962) designated cod from northern Labrador to the northern region of the Grand Banks as comprising a single stock. Increasing evidence is suggesting that a separation between offshore migratory and inshore resident stock components exists. In contrast to a historical focus on offshore/migratory cod in this region, a large body of work since the last report has documented the presence of an inshore component of Atlantic Cod in 2J3KL which currently represents a significant portion of the overall stock (Bradbury *et al.* 2008). Tagging and telemetry data (Brattey and Healey 2003, 2005, 2007, Brattey *et al.* 2008a) and hydro-acoustics (DFO, 2008) provide strong support for the conclusion that there is a resident inshore component of northern cod that over-winters in Smith Sound and disperses around the inshore area during summer months. Recent work has demonstrated the presence of a genetically isolated inshore population in Gilbert Bay, Labrador, which is distinct from Newfoundland inshore cod and suggests the potential for fine-scale genetic and adaptive divergence within the coastal stock component (Ruzzante *et al.* 1998; Beacham *et al.* 2002). Moreover, there is recent evidence of a renewed presence of cod in the offshore and of offshore cod making the traditional migration to the Northeast Newfoundland coast in the summer months (Worcester *et al.* 2009, Brattey, J. pers. comm.).

Life History

Age at maturity has changed significantly since the 1950s. The estimated age at 50% mature was 6-7 during the 1950s, declined to 6.0 during the 1960s, and is currently 4.9-5.7 for cohorts since 1990 with no apparent trend. Thus, in an unfished state, generation time is estimated to be 6+(1/0.2) = 11yr, yielding a three-generation time period of 33 yr. These declines in age at maturity have been attributed to fishery - induced evolutionary changes in life history of the stock (Olsen *et al.* 2004, 2005). Though the impact of life history changes on the productivity of the stock is unknown, fecundity in 2J cod was examined by Fudge and Rose (2008). They demonstrate that fecundity is currently >75% of pre-industrial levels suggesting a compensatory effect; however, the exact mechanism remains unclear.

Abundance Trends

Long-term abundance estimates are primarily available for the mature portion of the offshore stock component and are available in two types. At present there is no accepted VPA formulation for 2J3KL (See Brattey *et al.* 2008b for the 2008 assessment). VPA estimates are available from Baird *et al.* (1992) for the years 1962 to 1977 and from Bishop *et al.* (1993) for the years 1978 to 1992. In the absence of contemporary VPA-based estimates, temporal trends in abundance were examined using two approaches. First areal expansions of survey abundance were calculated using the number of trawlable units in the survey area and the average catch at age per tow (See Worcester *et al.* 2009). This was based on the autumn RV survey which has been conducted since 1981. This period encompasses a transition from the Engel trawl to the Campelen trawl (1994) and as such all data presented are converted to Campelen equivalents (Figure A2a). Survey data presented here are based on "offshore index" strata and represent strata that have been fished most consistently since the start of the survey and were provided by J. Brattey, Fisheries and Oceans Canada. Second, the existing VPA estimates for 2J3KL were extended forward in time, as in the previous report (COSEWIC 2003), using a regression of VPA and RV-data for the period of overlap. To undertake this estimation, a regression of the (log) survey catch rate data (numbers per tow for individuals age 5 years and older) against the (log) VPA abundance estimates ($r=0.74$, $p<0.01$) was used incorporating the survey catch rate data from 1993 to 2007, to estimate numbers of individuals (Figure A2.). Irrespective of the data source, the 3-generation rate of decline experienced by northern cod exceeded 97% (Figure A2b, Table A1). Since 2003, both metrics show some increase in abundance (Figure A2b). A hydro-acoustic survey in the offshore from Hawke channel to the nose of the Grand Bank estimated biomass in 2007 at 2,600 t (3L), 4,000 t (2J) and 17,000 t (3K) (Mello and Rose 2008). Nonetheless, the current estimates for the 2J3KL offshore area are still historically low (<8% of 1980 levels).

Area of occupancy

Between 1983 and 1995 the area of occupancy for the offshore declined from approximately 260,000 km^2 to 80,000 km^2 and the D95 from 170,000 km^2 to approximately 50,000 km^2. Following an initial increase to 225,000 $km^2$and 140,000 km^2 for the area of occupancy and D95 respectively, there has been little recent change.

Threats to recovery

Directed harvest in 2J3KL is substantial though not entirely known. In 2003, most of the harvest was associated with an unusual inshore mortality event due to extremely cold water in Smith Sound (Colbourne *et al.* 2003). In 2006, 2007 and 2008, a directed "stewardship" fishery and a recreational fishery for cod were re-opened in the inshore with landings in 2006 of 2,679 t, including 380 t in the recreational fishery, 159 t in the sentinel surveys, and 45 t of bycatch of which 20 t came from the offshore. Similar landings were reported in 2007 with a total of 2,364 t including 2,192 t directed catch, 172 t as bycatch, and 182 t in the sentinel surveys. Total landings in 2008 increased to

4,162 t, including an estimate for recreational fisheries based on a telephone survey. Recreational fisheries landings prior to 2008 are unavailable and as such total harvest levels remain unknown. The impact of natural mortality in 2J3KL is poorly understood. It seems likely that high natural mortality contributed to the high total mortality experienced in the offshore in the late 1990s and up till 2002. The source of this high natural mortality remains under speculation and possible causes include increased marine mammal predation, or other ecosystem changes. Since 2002, it seems natural mortality has decreased significantly; however, the cause is unknown at present, nor is it known how long this period of low natural mortality will continue.

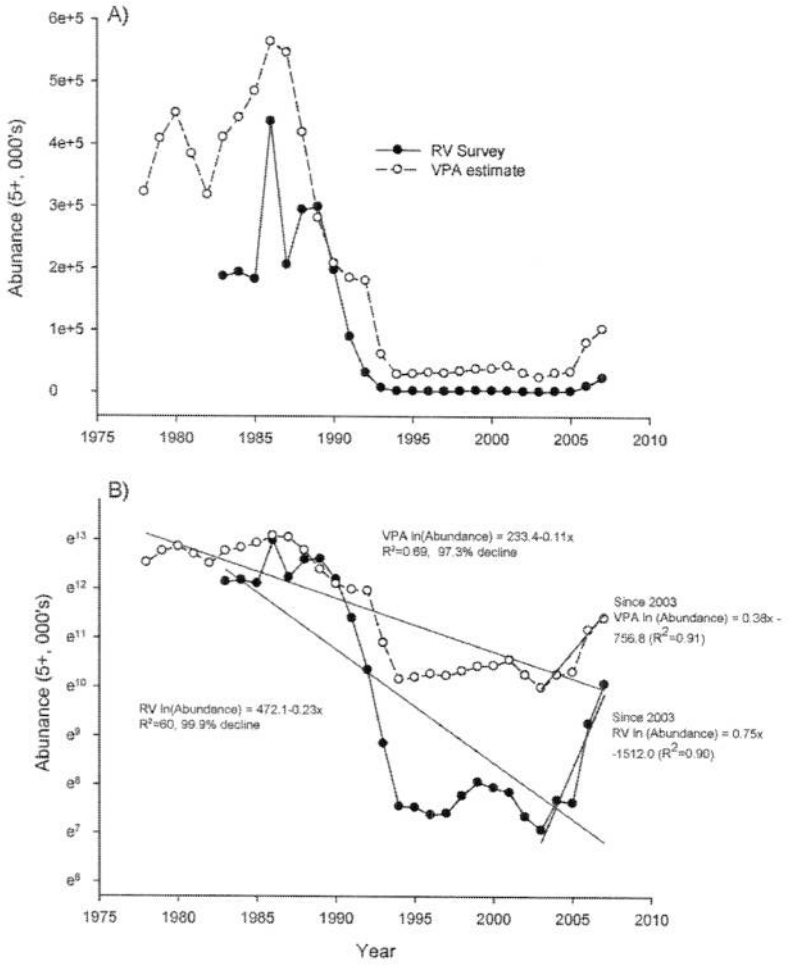

Figure A2. (A) Temporal variation in abundance of mature individuals in the northern cod stock (2J3KL). (B) Estimation of three-generation rate of decline. RV survey data from Worcester *et al.* 2009. VPA estimates have not been available since 1992 (Bishop *et al.* (1993); following COSEWIC (2003), presented data are an extrapolation based the relationship (r=0.74) between VPA abundance and RV survey abundance for the time period 1983 to 1992. This extrapolation is done for the purposes of rate of decline calculation only. Relationships associated with recent (since 2003) positive trends are also noted.