Shifting baselines in marine fish assessments: implications for perception of management and conservation status

by

Renée Préfontaine

Submitted in partial fulfillment of the requirements for the Degree of Honours Bachelor of Science in Marine Biology

at

Dalhousie University

Halifax, Nova Scotia, Canada

April 2009

TABLE OF CONTENTS

ABSTRACT

The declining state of oceans and fisheries worldwide has prompted the scientific community to engage in endeavours aimed at increasing the confidence one can have in the methods used to assess the status of fish stocks. These efforts are necessary as accurate assessments are fundamentally important for the successful management and conservation of commercially exploited fishes. One of the issues receiving a lot of attention recently is the phenomenon of shifting baselines. This occurs when a lack of historical data leads people to perceive stocks as healthy despite abundances having declined substantially over time. Here, I compare assessments of various marine fish stocks from the mid 1990's to the most recent assessments available and determine that 32% (n=81) of stocks have truncated time series. Effects of these truncations include concealment of historical spawning stock biomass maximum, reduction of population abundance variability and obscuring of past recoveries. These changes make it almost impossible to recognize historic maxima and trends in the population abundance. In turn this can result in unfounded or even obsolete management or conservation initiatives which have the potential to put fisheries in heightened risk of collapse. I conclude that these truncations are in fact causing a shifting baseline in the stocks which were investigated and that initiatives to incorporate historical data into assessments need to be further explored and considered in order to promote adequate management of fisheries.

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ICES: International Council on the Exploration of the Seas (international)

DFO: Department of Fisheries and Oceans (Canada)

NAFO: Northwest Atlantic Fisheries Organization (international)

NMFS: National Marine Fisheries Service (United States of America)

DETMCM: Department of Environment and Tourism, Marine and Coastal Management (South Africa)

IATTC: Inter-American Tropical Tuna Commission (international)

IPHC: International Pacific Halibut Commission (international)

WCPFC: Western and Central Pacific Fisheries Commission (international)

TAC: Total Allowable Catch

SSB: spawning stock biomass

SSB_{max}: spawning stock biomass maxima

SSB_{min}: spawning stock biomass minima

ACKNOWLEDGEMENTS

First and foremost I would like to thank my parents who provide me with continual support and believe in me no matter what. To my brother and sister; Ian you loved fish way before I did so this is definitely for you, Marjo you are living proof to me that I can do anything I want to, it's only a matter of how hard I'm willing to work for it so this is also for you. To the rest of my family and all my friends: thank you for the encouragement and the laughs.

To the Hutchings' lab; I am so grateful that I was allowed to spend this last year with such a group of wonderful individuals. To my office mates, thanks for the laughs and discussions as well as for putting up with my incessant chatter and questions.

I would like to acknowledge Coilin Minto for all the help he provided this summer and for the insightful tidbits of information he was always ready to share. I owe my eternal gratitude to Laura Weir for the immeasurable help and guidance she never failed to offer.

This study would not have happened without Daniel Ricard. Thank you for the countless hours of lessons on R, databases and everything in between, mostly in French of course!

I was very fortunate to have for co-supervisor Julia Baum. This project was her idea and through the year she provided me with support and help all the way from California.

Finally I would like to thank Jeff Hutchings for giving me the opportunity to work on this project as well as for his patience and help this past year.

INTRODUCTION

The overexploitation of marine resources is quickly decimating our oceans. Species are being pushed closer to the brink of extinction with every net, every trawl and every longline. Many fisheries and fish stocks, such as the northern Atlantic cod (*Gadus morhua*) off the coast of Newfoundland and Labrador, have collapsed (Hutchings & Myers 1994), populations like the Caribbean green turtle (*Chelonia mydas*) have suffered decreases of more than 90% (Bjorndal & Bolten 2003), while others (e.g. oceanic white tip shark (*Carcharhinus longimanus*) from the Gulf of Mexico which is a component of the Atlantic population) hover at approximately 1% of their known population maxima (Baum & Myers 2004). There is hope though; not all fisheries are overfished, the worldwide catch has been relatively stable in the last years (Hilborn et al. 2003) and we are coming up with better management strategies which only need to be better and more widely implemented (Beddington et al. 2007).

Management bodies such as International Council on the Exploration of the Seas (ICES), Department of Fisheries and Oceans (DFO), Northwest Atlantic Fisheries Organization (NAFO) and National Marine Fisheries Services (NMFS) are responsible for the proper management of fisheries. In order to do so, assessments are produced every year or so for each targeted exploited stock. These strive to estimate various measures of fish abundance such as the frequently used spawning stock biomass (SSB defined as the weight of all sexually mature fish in a population). These measures of abundance are quantified using data collected by commercial fishing vessels (i.e. catches) and fisheries-independent surveys, biological information about the stock, and an assortment of different population dynamics models (Hilborn & Walters 1992). These assessments also attempt to document important biological information concerning the species in question. Using all this information, restrictive measures such as total allowable catch (TAC) are decided upon and implemented in the fishery, often (but not always) with the goals of maximizing profits while promoting health of the fishery (Botsford et al. 1997).

When trying to examine the effect that exploitation has had on a fished population it is necessary for fisheries scientists to consider stock status and abundance over a number of years. In some stocks, this is relatively straightforward, due to well-documented fishing histories. On the other hand, some time series may be comparatively short due to the brief time elapsed since fishing began or a non-recording of catches in the early years of the fishery. In 2005 Rosenberg and his colleagues used historic fishing logs from Beverly, Massachusetts to model and extend the biomass time series of Scotian Shelf cod back 150 years. Their results show a massive decline in estimated biomass since 1850 which indicate that our contemporary perception of healthy or rebuilt cod stocks is erroneous (Rosenberg et al. 2005).

This is an example of a phenomenon called the "shifting baseline syndrome of fisheries". Daniel Pauly was the first to coin this term in 1995 although the phenomenon was noted years before in green turtles (Latin binomial) by Archie Carr (Bjorndall & Bolten 2003). Shifting baselines occur when the baseline considered by a scientist, or by the public, is the abundance level at the beginning of his career (Pauly 1995). Within a few generations the baseline may have shifted to a point where what is now the baseline is actually what was considered a depleted levels a number of years earlier (Sheppard

1995). The danger inherent to this phenomenon is the resulting complacency towards ailing marine resources and subsequent management and conservation failures which could ensue (Pauly 1995).

There is growing concern in the scientific community over this issue and as such a number of examples are being uncovered, using a variety of historical data sources. The former abundance of pelagic sharks in the Gulf of Mexico is largely unknown, but was recently estimated to have decreased by 90-99% in some species based on a comparison of exploratory research surveys from the 1950's and observer data from commercial longline vessels (Baum & Myers 2004). McClenachan and her colleagues used historical records in 2006 such as observations on nesting beaches from the 1900's and historical harvest data to determine that contemporary assessments are not representative of past abundances of now endangered Caribbean turtles. In 2008 McClenachan used historical pictures of trophy fish taken by a single photographer from 1956-1985 to ascertain that there was a decrease in size and species composition of marine fish targeted by sport fishermen in the Florida Keys. Turtles were extensively exploited pre-historic populations to a point where even Columbus landing in the Caribbean in 1492would have seen depleted turtle populations; something which is rarely taken into consideration by scientists today (Bjorndall & Bolten 2003). In 2005 Sáenz-Arroyo and his colleagues used interviews with fishermen in the Gulf of California to uncover a shifting baseline apparent amongst different generations of fishermen and the number of species and sites they consider depleted.

This project takes a new and different approach to the study of shifting baselines in that it looks at a number of different stocks and different species at once. The project stemmed from the observation that some recent marine fish stock assessments have truncated time series relative to those in earlier assessments. Consequently the primary objective of this study is to determine if these truncations create shifting baselines ; the secondary objectives are to determine how prevalent the truncation of time series used in fisheries stock assessment models is, and what effect, if any; these truncations have on perception of stock status. In order to achieve this, I contributed to the development of a new fisheries database containing data on various marine fish stocks from the most recent stock assessments, and compared each marine fish stock's recent assessment to its assessment in the Myers Stock Recruitment database (from the mid 1990's) in order to determine the proportion of stocks which have suffered truncations. The reasons for these truncations are investigated through a literature review and these truncations are then studied by comparing plotted time series from the two assessments of different time periods. Finally, the implications for management and conservation of fisheries are considered.

METHODS

Data sources

The present study utilized data from two different databases of stock assessments for commercially exploited marine fish populations. The first database is an established one, the Myers Stock Recruitment Database, which is referred to herein as RAM I. The second database, RAM II, is a developing database to which this study contributed.

RAM I

The Ransom Myers' Stock Recruitment Database was originally developed in the mid-1990s by the Ransom Myers, Nick Barrowman and Jessica Bridgson (Myers et al. 1995). It contains maps showing the worldwide location of species included in the database as well as plots and time series data for variables such as spawning stock biomass, recruitment, fishing mortality and landings for more than 600 marine and anadromous fish populations. RAM I was accessed primarily through the original database (http://ram.biology.dal.ca/~myers/welcome.html), but also through the new database (RAMII), which contains both new stock assessments, the original RAM I database and work previously undertaken by Dr. Julia K. Baum in 2004.

RAM II

The RAM II Stock-Recruit Database is a project initiated in late 2007 by Drs. Baum and Hutchings, and by former students of Ram Myers: Daniel Ricard and Coilin Minto. Information regarding the project can be obtained from the RAM Legacy website: http://www.marinebiodiversity.ca/RAMlegacy/srdb. This database will be referred to as the RAM II database throughout the remainder of this paper. The goal of this (now expanded) group of scientists was to perform a complete overhaul of RAM I by completely updating the data for each stock, adding new stocks when possible and placing all this material in a relational open-source database management system (postgreSQL). This new management system placed the data in tables which were all interconnected; this high connectivity in the data provided a very dynamic database and allowed for easy querying and analysis of the data. The RAM II database also contained time series data for each stock as well as biological reference points and information on the assessment, management and life history for each stock. At the time of writing, an upload of the data from the RAM I database was in process; 83 stocks from RAM I were available through the RAM II postgreSQL database.

The aim of the RAM II database was to include assessment information on all stocks from the DFO, NMFS, ICES and NAFO, as well as stocks from Australia, the International Pacific Halibut Commission and the top 20 fisheries in the world (ranked by catch). For each stock, the most recent assessment undertaken by the managing body was reviewed in order to be added to the RAM II database. Each assessment was read and examined for relevant data. These data were then extracted manually or electronically and entered in a Microsoft Excel template containing three pages. The first, called "Meta", contained information about the assessment, the author of the assessment and the person responsible for the entering of the data. The second page included information about the time series and the life history of the stock, such as age or length at 50% maturity, and biological reference points such as B_{LIM} (the lowest observed spawning stock biomass in previous assessments and fishing moratorium years). The third page was comprised of various time series data available for each stock: fishing mortality, recruitment, spawning stock biomass, total biomass, total catch and total landings. These spreadsheets and the corresponding pdf documents corresponding to each assessment were uploaded to the database. Each stock uploaded to the database is quality-controlled by cross-checking the data in the database with those in the original assessment document and examined for mistakes. Each person completing assessments is then expected to perform a quality control check on the data entered for each stock (this has yet to be done for the majority of assessments).

During the summer of 2008, I completed the update of the greater majority of the DFO stocks in the North Atlantic. Roughly 45 assessments were reviewed, for about 15 of these the authors of the original stock assessment had to be contacted in order to obtain additional information missing from the assessments. At the time of writing, 31 of these assessments had been uploaded to the RAM II database and were awaiting quality control checks.

Analysis

Database and Time Series Comparison

The databases were compared by checking the RAM II database against the internet-based RAM I database with the help of the list compiled by Dr. Baum in 2004. This collation resulted in a list of the stocks from the mid-1990's and their most recent counterparts. This list was used as the basis for Table 1 which comprised of all these stocks, including the years of each time series as well as taxonomic, management and area information. For each time series, the number of time series that had been truncated or lengthened was determined and average periods of truncation or lengthening were also estimated.

A subset containing stocks with early (mid-1990's) and recent spawning stock biomass time series available in the RAM II databases was used for the rationale behind truncations and plotting components of the analysis. The result was a set of 16 stocks each containing two spawning stock biomass time series, one from the RAM I database and one from the RAM II database. This sample was then again separated into two: the stocks for which the more recent time series was shortened and those for which this same time series had been lengthened. For each stock, the literature was reviewed in order to find reasons for these truncations. A plot of spawning stock biomass through the years comparing the RAM I and the RAM II databases was then created with the use of the statistical programming software R for each stock. The maximum and minimum spawning stock biomass was calculated for each time series. The plots were then examined to determine the effect that these changes in time series length had on the perception of stock status. The stocks were then classified according to four possible effects on perception: no change, change in spawning stock biomass maximum, change in overall trends or fluctuations, and obscuring of precedents in minimum or maximum spawning stock biomass. The assessments corresponding to the truncated stocks were also reviewed in hope of identifying reasons for time series truncations, when they occurred.

RESULTS

Comparison of mid 1990's and contemporary marine fish assessments

The review of the literature used to obtain data on each stock provided no insight as to the reasons for the truncations of time series.

In total there were 81 marine fish stocks in common between the two databases (Table 1) with the three following families containing the majority of these stocks: Gadidae (36%), Clupeidae (21%) and Pleuronectidae (15%). Accordingly, Atlantic cod

(*Gadus morhua*) was by far the species with the greatest number of stocks moreover this specie also appears to be among the stocks with the longest documented history of fishing.

ICES assessed the greatest number of stocks identified in Table 1 with 57% of the total; the second most abundant management body was the DFO with17% of the stocks (Table 1). As seen in Table 2 both of these assessment agencies had roughly 45% of their stocks with time series for which the initial year of the time series differed between the RAM I and RAM II databases. Approximately 65% of these stocks in both of these management groups had been truncated (n=22 for ICES and n=6 for DFO). For all assessment agencies (The Western and Central Pacific Fisheries Commission (WCPFC) being the only exception, as it was the only agency that had produced no truncated stocks), the stocks were always truncated by a greater number of years than they were lengthened. In more than half of the 81 stocks, the two time series started at a different year; in 63% of these the more recent time series was truncated, that is, it was shorter than the time series presented in the RAM I database. These stocks were truncated by an average of 23.7 years while the lengthened stocks gained an average of 4.6 years.

Table 1: Summary of the 81 stocks common to the RAM 1 (assessments from the mid 1990's) and RAM II (most recent assessments available) databases.

Family	Scientific Name	Common Name	Management Authority	Area	SSB years My	SSB years New
Scombridae	Thunnus alalunga	Albacore tuna	WCPFC	S. Pacific Ocean	1962-1993	1959-2007
Pleuronectidae	Hippoglossoides platessoides	American plaice	NAFO	Grand Banks	1965-1986	1960-2007
Pleuronectidae	Hippoglossoides platessoides	American plaice	NAFO	Flemish Cap	1988-1996	1988-2005
Engraulidae	Engraulis encrasicolus	Anchovy	ICES	Bay of Biscay	1987-1994	1987-2007
Scombridae	Thunnus thynnus	Atlantic bluefin tuna	NMFS	W. Atlantic	1970-1993	1970-2007
Gadidae	Gadus morhua	Atlantic cod	DFO	Newfoundland	1962-1992	1995-2006
Gadidae	Gadus morhua	Atlantic cod	DFO	N. Gulf of St. Lawrence	1974-1997	1974-2007
Gadidae	Gadus morhua	Atlantic cod	DFO	St. Pierre Bank	1959-1993	1977-2004
Gadidae	Gadus morhua	Atlantic cod	DFO	S. Gulf of St. Lawrence	1950-1993	1971-2007
Gadidae	Gadus morhua	Atlantic cod	DFO	E. Scotian Shelf	1958-1993	1970-2002
Gadidae	Gadus morhua	Atlantic cod	DFO	Georges Bank	1978-1998	1978-2003
Gadidae	Gadus morhua	Atlantic cod	ICES	Baltic Sea	1970-1992	1970-2007
Gadidae	Gadus morhua	Atlantic cod	ICES	Baltic Sea	1970-1995	1966-2006
Gadidae	Gadus morhua	Atlantic cod	ICES	Norwegian Coastal	1984-2000	1984-2006
Gadidae	Gadus morhua	Atlantic cod	ICES	Faroe Plateau	1961-1995	1961-2006
Gadidae	Gadus morhua	Atlantic cod	ICES	Iceland	1928-1995	1955-2006
Gadidae	Gadus morhua	Atlantic cod	ICES	Irish Sea	1968-1994	1968-2006
Gadidae	Gadus morhua	Atlantic cod	ICES	Kattegat	1971-1992	1971-2006
Gadidae	Gadus morhua	Atlantic cod	ICES	NE Arctic	1946-1993	1946-2006
Gadidae	Gadus morhua	Atlantic cod	ICES	North Sea	1963-1994	1963-2006
Gadidae	Gadus morhua	Atlantic cod	ICES	West of Scotland	1966-1992	1978-2006
Gadidae	Gadus morhua	Atlantic cod	NAFO	S. Grand Banks	1959-1993	1959-2007
Gadidae	Gadus morhua	Atlantic cod	NMFS	Georges Bank	1963-1996	1978-2007
Gadidae	Gadus morhua	Atlantic cod	NMFS	Gulf of Maine	1963-1997	1982-2007
Scombridae	Thunnus obesus	Bigeye tuna	IATTC	E. Pacific Ocean	1975-2000	1975-2007
Osmeridae	Mallotus villosus	Capelin	ICES	Iceland	1979-1997	1978-2006
Osmeridae	Mallotus villosus	Capelin	ICES	Barents Sea	1973-1996	1973-2006
Soleidae	Solea vulgaris	common European sole	ICES	Celtic Sea	1972-1991	1971-2006
Soleidae	Solea vulgaris	common European sole	ICES	Skagerrak & Kattegat	1984-1990	1984-2007
Soleidae	Solea vulgaris	common European sole	ICES	Irish Sea	1970-1992	1970-2006
Soleidae	Solea vulgaris	common European sole	ICES	North Sea	1957-1992	1957-2006
Soleidae	Solea vulgaris	common European sole	ICES	Western Channel	1969-1991	1969-2006
Soleidae	Solea vulgaris	common European sole	ICES	Bay of Biscay	1979-1991	1984-2006

Pleuronectidae	Pleuronectes platessa	European Plaice	ICES	Eastern Channel	1980-1991	1980-2006
Pleuronectidae	Pleuronectes platessa	European Plaice	ICES	Skagerrak & Kattegat	1978-1991	1978-2005
Pleuronectidae	Pleuronectes platessa	European Plaice	ICES	Irish Sea	1964-1992	1964-2006
Pleuronectidae	Pleuronectes platessa	European Plaice	ICES	North Sea	1957-1991	1957-2006
Pleuronectidae	Reinhardtius hippoglossoides	Greenland halibut	ICES	NE Arctic	1970-1994	1964-2006
Pleuronectidae	Reinhardtius hippoglossoides	Greenland halibut	NAFO	Newfoundland	1969-1988	1975-2006
Clupeidae	Brevoortia patronus	Gulf menhaden	NMFS	Gulf of Mexico	1964-1991	1964-2004
Gadidae	Melanogrammus aeglefinus	Haddock	ICES	Faroe Plateau	1961-1995	1957-2007
Gadidae	Melanogrammus aeglefinus	Haddock	ICES	Iceland	1962-1990	1979-2007
Gadidae	Melanogrammus aeglefinus	Haddock	ICES	NE Arctic	1950-1994	1950-2006
Gadidae	Melanogrammus aeglefinus	Haddock	ICES	Rockall Bank	1985-1994	1991-2007
Gadidae	Melanogrammus aeglefinus	Haddock	ICES	West of Scotland	1965-1993	1978-2006
Merlucciidae	Merluccius merluccius	Hake	ICES	Northern Stock	1978-1998	1978-2007
Merlucciidae	Merluccius merluccius	Hake	ICES	Southern Stock	1982-1998	1982-2007
Clupeidae	Clupea harengus	Herring	DFO	4R Fall Spawners	1973-1987	1973-2003
Clupeidae	Clupea harengus	Herring	DFO	4R Spring Spawners	1973-1987	1965-2004
Clupeidae	Clupea harengus	Herring	ICES	Baltic Sea	1970-1990	1991-2006
Clupeidae	Clupea harengus	Herring	ICES	Baltic, Bothnian Sea	1974-1990	1973-2006
Clupeidae	Clupea harengus	Herring	ICES	Baltic, Bothnian Bay	1974-1989	1980-2006
Clupeidae	Clupea harengus	Herring	ICES	Iceland Summer Spawners	1947-1996	1986-2007
Clupeidae	Clupea harengus	Herring	ICES	Northern Irish Sea	1972-1990	1961-2006
Clupeidae	Clupea harengus	Herring	ICES	North Sea	1947-1989	1960-2006
Clupeidae	Clupea harengus	Herring	ICES	Baltic, Gulf of Riga	1970-1990	1977-2007
Scombridae	Scomberomorus cavalla	King Mackerel	NMFS	Gulf of Mexico	1952-1990	1992-2001
Scombridae	Scomber scombrus	Mackerel	ICES	Northeast Atlantic	1984-2000	1972-2006
Scophthalmidae	Lepidorhombus whiffiagonis	Megrim	ICES	ICES Division VIIIc & Ixa	1986-1994	1986-2006
Gadidae	Trisopterus esmarkii	Norway Pout	ICES	North Sea	1974-1994	1983-2007
Gadidae	Gadus macrocephalus	Pacific cod	NMFS	Gulf of Alaska	1978-2000	1977-2007
Pleuronectidae	Hippoglossus stenolepis	Pacific halibut	IPHC	N. Pacific	1935-1981	1996-2009
Clupeidae	Clupea pallasii	Pacific herring	DFO	Central Coast, B.C.	1951-1991	1951-2007
Clupeidae	Clupea pallasii	Pacific herring	DFO	Prince Rupert	1951-1991	1951-2007
Clupeidae	Clupea pallasii	Pacific herring	DFO	Queen Charlotte Islands	1951-1991	1951-2007
Clupeidae	Clupea pallasii	Pacific herring	DFO	Strait of Georgia	1951-1991	1951-2008
Clupeidae	Clupea pallasii	Pacific herring	DFO	West Coast of Vancouver Island	1951-1991	1951-2009
Scorpaenidae	Sebastes alutus	Pacific ocean perch	NMFS	Pacific Coast	1960-1992	1956-2007
Gadidae	Pollachius virens	Pollock	ICES	Faroe Plateau	1961-1995	1961-2006
Gadidae	Pollachius virens	Pollock	ICES	NE Arctic	1960-1993	1960-2006

Scorpaenidae	Redfish species	Redfish species	NAFO	Flemish Cap, mixed species	1989-1998	1989-2006
Pleuronectidae	Lepidopsetta bilineata	Rock sole	DFO	Hecate Strait	1946-1969	1945-2001
Ammodytidae	Ammodytes marinus	Sand eel	ICES	North Sea	1976-1990	1983-2007
Clupeidae	Sardinops sagax	Sardine	DETMCM	S. Africa	1950-1980	1984-2006
Clupeidae	Sprattus sprattus	Sprat	ICES	Baltic Sea	1974-1990	1974-2007
Paralichthyidae	Paralichthys dentatus	Summer flounder	NMFS	Mid Atlantic Coast	1982-1990	1982-2007
Gadidae	Merlangius merlangus	Whiting	ICES	West of Scotland	1965-1992	1985-2007
Scorpaenidae	Sebastes entomelas	Widow rockfish	NMFS	Pacific Coast	1970-1990	1958-2006
Scombridae	Thunnus albacares	Yellowfin tuna	IATTC	E. Pacific Ocean	1967-1992	1975-2007
Pleuronectidae	Limanda ferruginea	Yellowtail flounder	NMFS	Cape Cod & Gulf of Maine	1973-1996	1985-2007
Pleuronectidae	Limanda ferruginea	Yellowtail flounder	NMFS	S. New England & Mid Atlantic	1973-1996	1973-2007

Table 2: Information on stocks common to the RAM I and RAM II databases according to management body. Truncated stocks are those where the start year of the RAM II time series is later than the RAM I, elongated stocks are those where the RAM I time series starts later than the RAM II time series. Abbreviations stand for: Department of Environment and Tourism, Marine and Coastal Management (South Africa), Department of Fisheries and Oceans, Inter-American Tropical Tuna Commission, International Council on the Exploration of the Seas, International Pacific Halibut Commission, Northwest Atlantic Fisheries Organization, National Marine Fisheries Service and Western and Central Pacific Fisheries Commission.

Management Authority	# stocks in both databases	# stocks with altered years	# stocks truncated	mean # of years truncated	# with earlier start year	mean # of years elongated
DETMCM	1	1	1	34	0	NA
DFO	14	6	4	21	2	4.5
IATTC	2	1	1	8	0	NA
ICES	46	22	14	14.4	8	5
IPHC	1	1	1	61	0	NA
NAFO	5	2	1	6	1	5
NMFS	11	7	4	21.5	3	5.7
WCPFC	1	1	0	NA	1	3
TOTAL	81	41	26	165.9	15	23.2
AVERAGE	10.125	5.125	3.25	23.7	1.875	4.64

Time Series Comparisons

There were 4 main general effects observed in the present study as a result of shifts in the time series start year, be it a truncation or a lengthening of the time series: (i) obscuring of the spawning stock biomass historical maximum or minimum ($SSB_{max/min}$), (ii) suppression of population abundance variability, (iii) concealment of precedents in SSB_{max}, SSB_{min}, recovery or decline, and (iv) no effect.

(i) Estimates of historical spawning stock biomass maximum or minimum

There are 6 stocks whose time series truncations have caused the estimations of historical spawning stock biomass maximum or minimum to be obscured (Figure 1).

Figure 1a compared the RAM I and RAM II time series for herring (*Clupea harengus*) in the North Sea assessed by ICES (HERRNS). The RAM II time series in this case underwent a truncation of 13 years; without these additional years it was impossible to know that historically the estimate of spawning stock biomass maximum was almost 4.5 million metric tonnes while in the more recent assessments this number is estimated to be roughly 2 million metric tonnes. The truncated time series also indicated that the decline experienced by this stock was of a lesser magnitude than it actually was, as well as showing that contemporary levels were only about half of the historic estimate of $SSB_{max.}$

Icelandic haddock (*Melanogrammus aeglefinus*), another stock managed by ICES (HADICE), underwent a 17 year truncation between the RAMI and RAMII assessments (Figure 1b). This truncation confuses the SSB_{max} and would lead it to be perceived as 180 thousand metric tonnes instead of its historic value of 355 thousand metric tonnes. The RAM II time series suggests that spawning stock biomass is currently at an all time high while the addition of the 17 truncated years shows that in fact it is probably not.

As shown in Figure 1c the haddock stock west of Scotland under ICES management (HADVIa) suffered a 13 year truncation. This truncation concealed the historical SSB_{max} and led it to appear to be nearly 60 thousand tonnes lower than it was previously estimated.

The Icelandic cod stock is regulated by ICES (CODICE). The 27 year truncation it has undergone also leads to a change in perception of the SSB_{max} (Figure 1d). The shortened time series from the RAM II database gave a SSB_{max} of roughly 1.1 million metric tonnes while the RAM I time series indicated that this metric was 1.9 million metric tonnes, nearly two-fold higher.

In Figure 1e, the 12 year truncation imposed on the cod stock west of Scotland (CODVIa managed by ICES) affected one's perception of maximum spawning stock biomass. The RAM I SSB_{max} was more than 10 thousand metric tonnes greater than the truncated maximum presented in the RAM II database. This change in SSB_{max} also caused a change in one's perception of historical decline of this stock; the overall decline was much steeper with the addition of those 12 years and the increase in SSB_{max}.

Finally, the summer spawning Icelandic herring stock under ICES administration with its 39 year truncation was the stock with the greatest truncation in this sample (HERRIsum Figure 1f). In contrast to the truncated stocks presented thus far, this truncation affected the spawning stock biomass minimum instead of the maximum. In fact the SSB_{min} appeared to be roughly 275 thousand metric tonnes which was more than twice the historical value of 106 thousand metric tonnes seen in the RAM I time series.

(ii) Population Abundance Variability

There were 4 stocks that exhibited time series in which the removal of a number of years obscured a pattern of population abundance variability, these stocks' time series were all truncated.

In Figure 1c, for example, the 13 year truncation of the haddock stock west of Scotland (HADVIa) obscured the tendency that this stock had to fluctuate. With the additional 13 years that were truncated the RAM II time series was seen to go through 3 cycles of oscillation while without these years the oscillation was not noticeable.

The Icelandic cod stock seen in Figure 1d also suffered the same effect from its 27 year truncation. The RAM I time series revealed a clear fluctuating pattern while the truncated RAM II time series only showed a pattern of decline. Although after the time of truncation the stock seemed to have stopped oscillating, this modification to the length of the time series concealed the fact that this stock had once experienced substantial fluctuations in abundance.

The same could be said of the cod stock in the North Atlantic Fisheries Organization (NAFO) Division 4VsW (COD4VsW; Figure 2a). Under the authority of the DFO, this stock assessment experienced a 12 year truncation. With this truncation, a fluctuating pattern could be discerned in the RAM II time series, the additional years that were truncated helped to reinforce this appearance of population fluctuation.

As previously mentioned, the 39 year truncation of the summer spawning herring stock in Iceland was seen in Figure 1f. The RAM II time series showed a great peak in the spawning stock biomass in 2001 preceded by two smaller peaks the late 1980's and early 1990's. However, if this data set had not been truncated it would also have shown that similar peaks had also occurred before in 1962.

(iii) Precedents in recovery and spawning stock biomass levels

There were 5 stocks (4 truncated and 1 lengthened) whose time series length modification concealed the fact that recoveries or spawning stock biomass peaks similar to those observed in the contemporary time series had occurred in the past.

The truncation in the Icelandic haddock stock seen in Figure 1b also concealed an earlier partial recovery to similar levels. The recovery that occurred, which started roughly in 2000 and can be seen in the RAM II time series, has a counterpart in the mid-1970's, as observed in the RAM I time series.

The haddock stock on Rockall Bank (HADROCK), which is off the west coast of Scotland, was under the management authority of ICES. In this case, the RAM II time series had been truncated by only 6 years (Figure 3a). In the truncated series, there is a recent recovery from low levels (6913 metric tonnes) starting in 2001. Addition of the truncated years identifies a precedent to this recovery starting in 1990.

There were two instances of recoveries (1980 and 2000) of spawning stock biomass in the RAM II time series of the haddock stock west of Scotland (Figure 1c). The one which started in 2000 was a recovery to 103 thousand metric tonnes. The nontruncated time series reveals a precedent for these recoveries starting in 1968; although this one was of a much greater magnitude than even the recovery occurring in 2000 in the RAM II time series.

Figure 3b illustrates the RAM I and RAM II time series for herring in the northern Irish Sea (HERRNIRS). This stock was managed by ICES and the RAM II time series extended an additional 11 years before the RAM I time series started. This lengthening of the time series shows that there had been a precedent to the very low contemporary spawning stock biomass levels and that the stock has recovered from levels even lower than contemporary levels.

As mentioned earlier, the cod stock situated west of Scotland in ICES area VIa (Figure 1e) showed a truncated RAM II time series which misidentified the historical SSB_{max}. The addition of the truncated years shows that the peak seen in the RAM II time series around the late 1980’s was not unusual, as it had a precedent in the late 1960’s.

(iv) No effect

The following 7 stocks were not affected by modifications to the length of their time series (6 elongations and 1 truncation) (Figure 4).

The American plaice (*Hippoglossoides platessoides*) stock on the Grand Bank off Newfoundland (NAFO Divisions 3LNO) was under the jurisdiction of NAFO (Figure 4a). This stock‘s RAM II time series had been extended 5 years earlier from the year at which the RAM I series began. In this case, the lengthening of the time series had no effect on one's perception of the dynamics of the stock. Having acknowledged that, for the period of time during which both time series have data, the RAM II series showed a population decrease followed by an increase, while the RAM I time series showed a population decrease followed by stability (AMPL3LNO Figure 4a).

The Icelandic capelin (*Mallotus villosus*) stock, managed by ICES (CAPEICE), was extended back 1 year earlier than its RAM II time series; this extension had no discernable effect on one's perception of stock status Figure 4b). The RAM II time series was also prolonged 9 years over which time despite fluctuations the stock abundance remained relatively similar to levels seen before the extension. Over the period where the RAM I and the RAM II time series occur simultaneously the data point are identical but offset by one year.

ICES managed a stock of herring in the Bothnian Sea (area connected to the Baltic sea, between Sweden and Finland) and the most up-to-date time series for this stock extended one year earlier than that of the RAM I time series as well as 16 years later; this one year extension backwards caused no change in perception of stock abundance but the additional 16 years showed that overall the abundance decreased slightly between 1990 and 2006 (HERR30 Figure 4c).

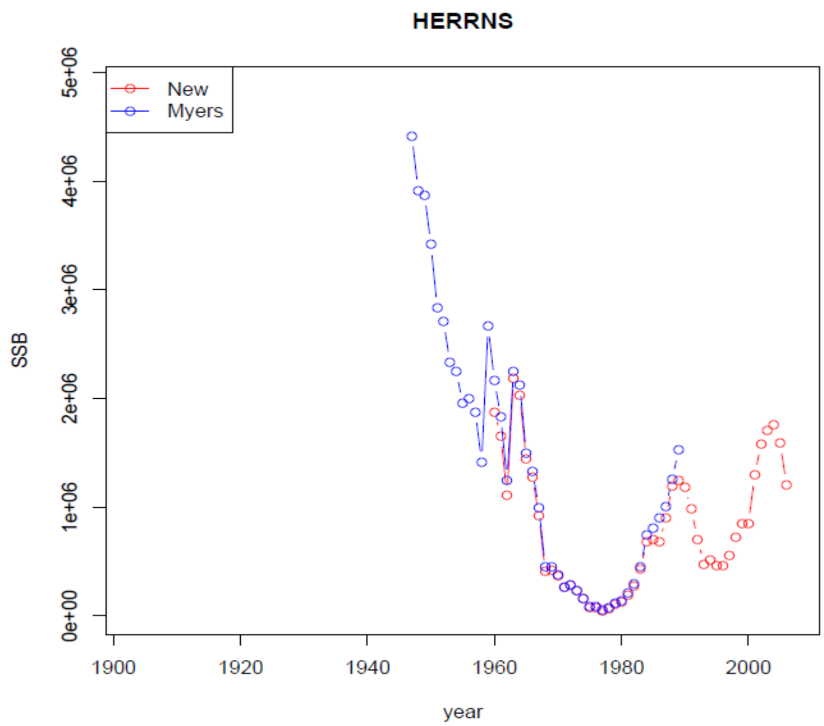
In Figure 4d, the RAM I and RAM II time series are shown for haddock on the Faroe Plateau (area located between Iceland, Scotland and Norway), which is assessed by ICES (HADFAPL). In this case, the RAM II time series stretches back 4 years earlier than the RAM I series, and also extends forward 7 years. This lengthening of the time series had no effect on one's perception of stock status.

The stock of Norway pout (*Trisopterus esmarkii*) in the North Sea (Figure 4e) was assessed by ICES (NPOUTNS). The RAM II time series in this stock experienced a 9 year truncation which had no discernable effect–although it does show that prior to the early-1980s peak that the stock had been at lower levels

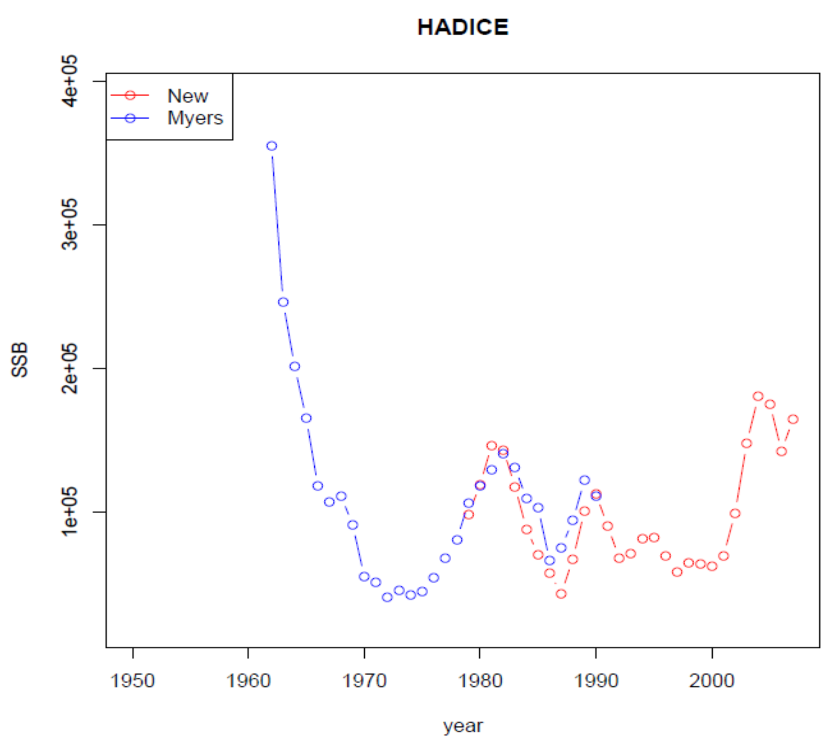
Figure 4f compared the RAM I and RAM II time series for the mackerel (*Scomber scombrus*) stock in the north east Atlantic assessed by ICES (MACKNEICES). For this stock, the latest time series extended 12 years earlier and 6 years later than the RAM II time series; the extension itself had no effect. However, the two time series displayed completely different trends over the years they had in common; the RAM I data showed an increase, while the RAM II abundance estimates were stable or decreasing.

The National Marine Fisheries Service (NMFS) managed the Pacific cod (*Gadus macrocephalus*) stock in the Gulf of Alaska (PCODGA). This stock's RAM II time series extended one year earlier and 7 years later than did the RAM I time series (Figure 4g). The lengthening itself had no effect but the two time series are extremely dissimilar with differences of 40 000 metric tonnes in spawning stock biomass or more between the two time series in the same year.

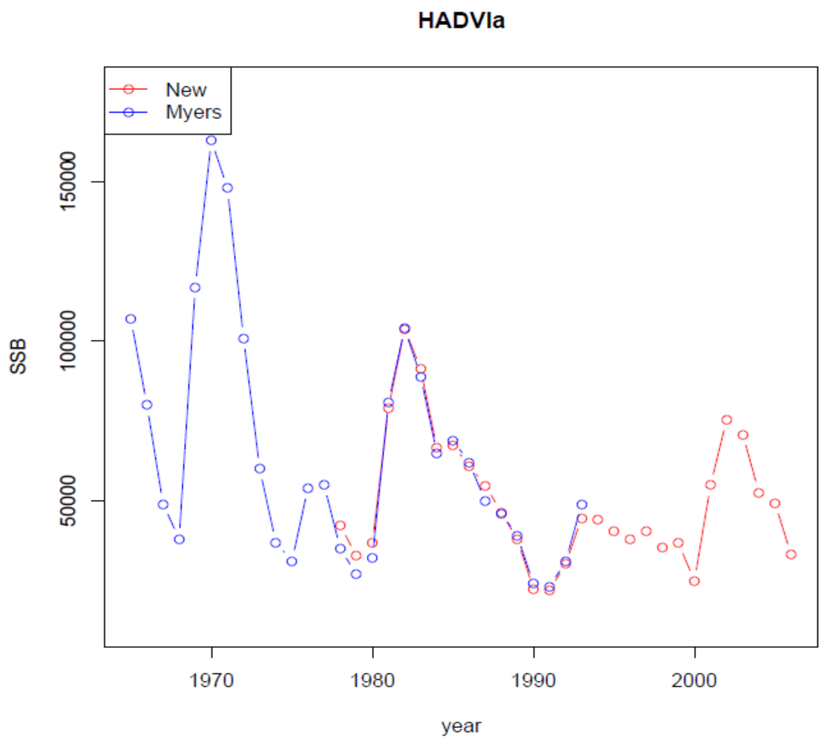
a)


HERRNS
New
Myers
SSB
0e+00
1e+06
2e+06
3e+06
4e+06
5e+06
1900
1920
1940
1960
1980
2000
year

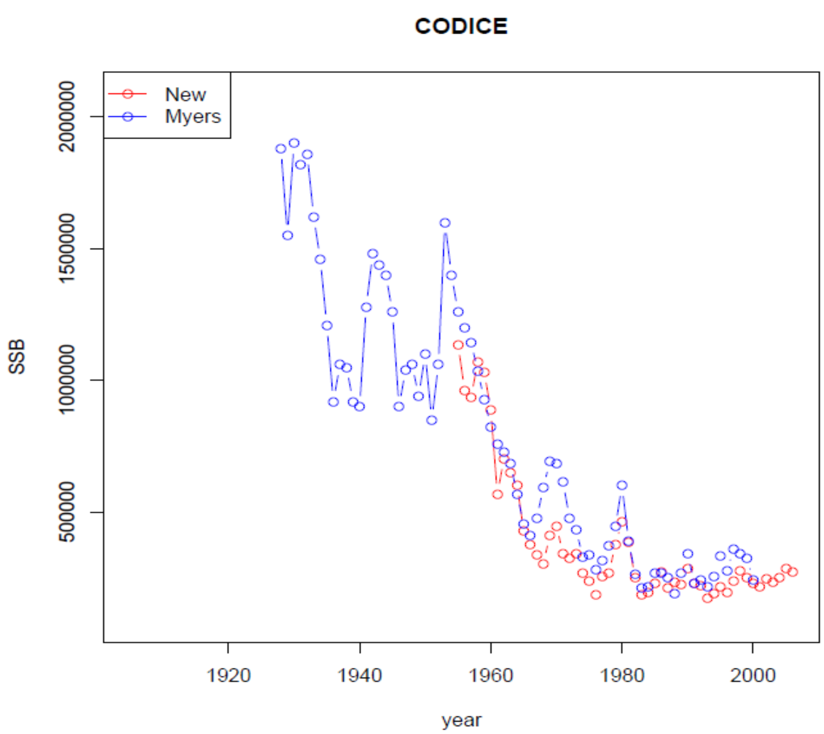
b)


HADICE
New
Myers
SSB
1e+05
2e+05
3e+05
4e+05
1950
1960
1970
1980
1990
2000
year

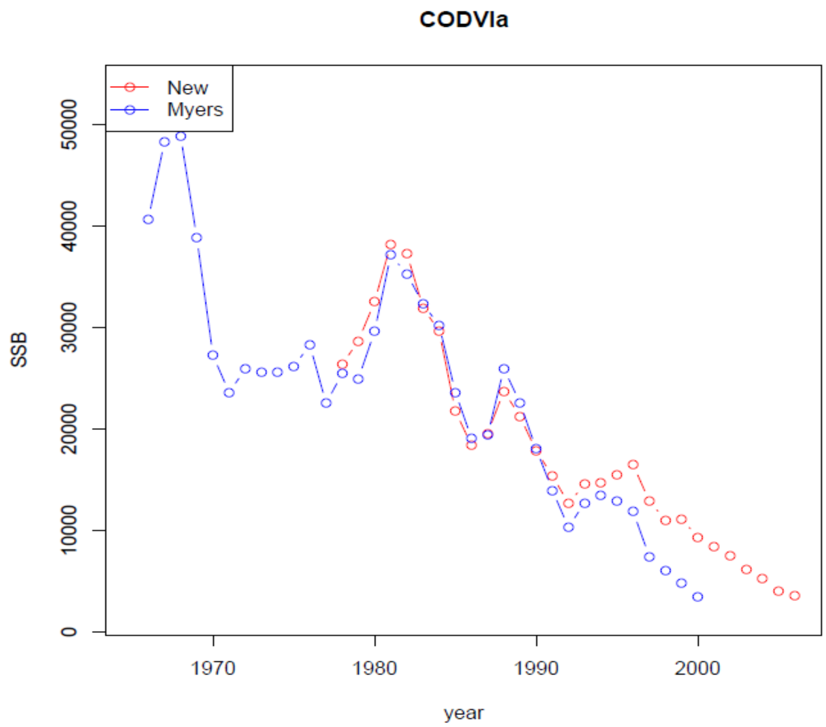
c)


HADVIa
New
Myers
SSB
50000
100000
150000
1970
1980
1990
2000
year

d)


CODICE
New
Myers
SSB
500000
1000000
1500000
2000000
1920
1940
1960
1980
2000
year

e)



f)

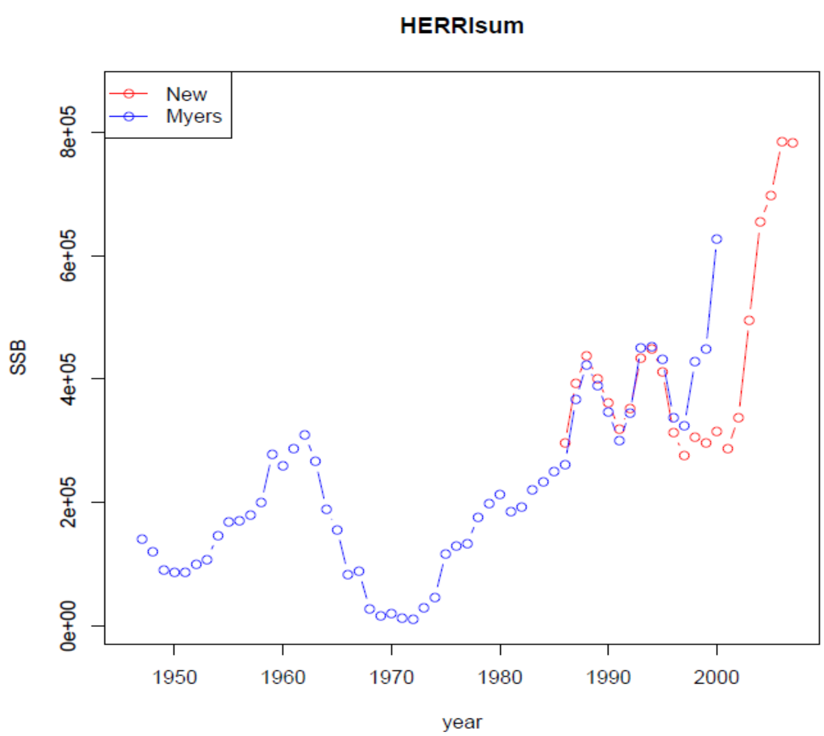


Figure 1: Plots showing the RAM I (blue) and RAM II (red) spawning stock biomass (in metric tonnes) time series for stocks whose truncations have concealed the historic spawning stock biomass maximum or minimum. a) North Sea Herring, b) Icelandic haddock, c)haddock west of Scotland, d)Icelandic cod, e) cod west of Scotland, f) summer spawning Icelandic herring.

a)

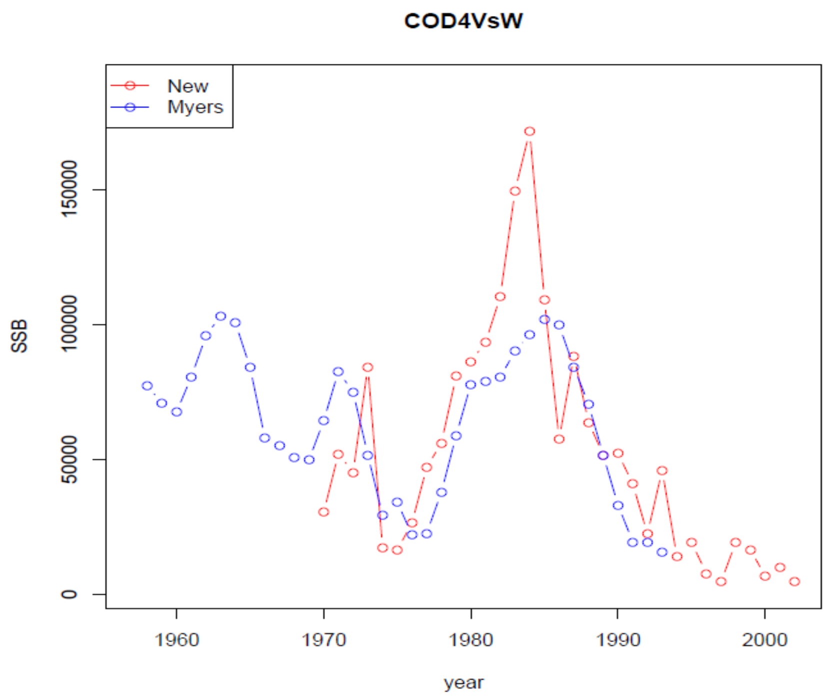
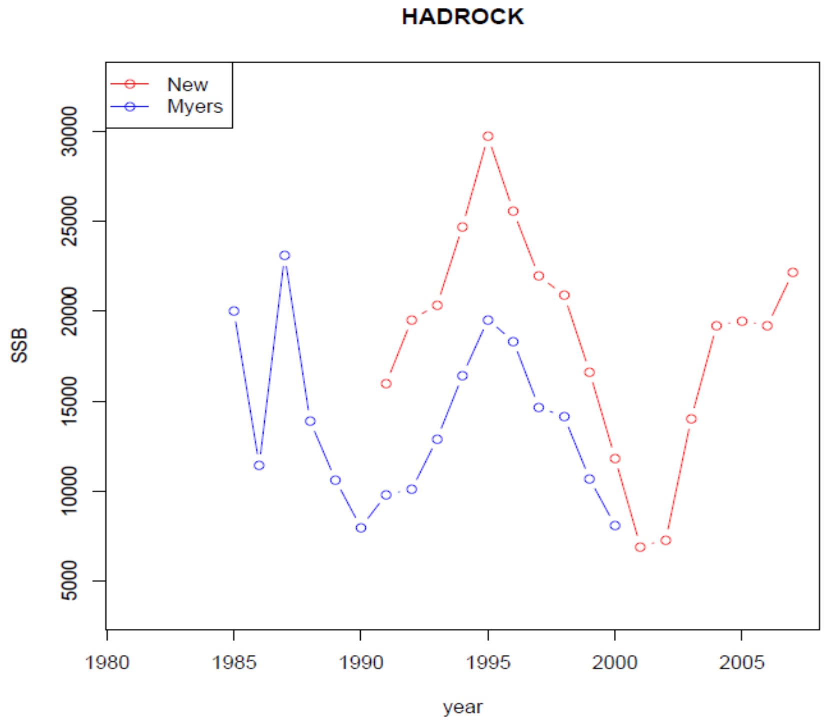


Figure 2: Plots showing the RAM I (blue) and RAM II (red) spawning stock biomass (in metric tonnes) time series for stocks whose truncations have concealed population abundance variability. a) cod in NAFO Division 4VsW, b) see Figure 1c, c) see Figure 1d, d) see Figure 1f

a)



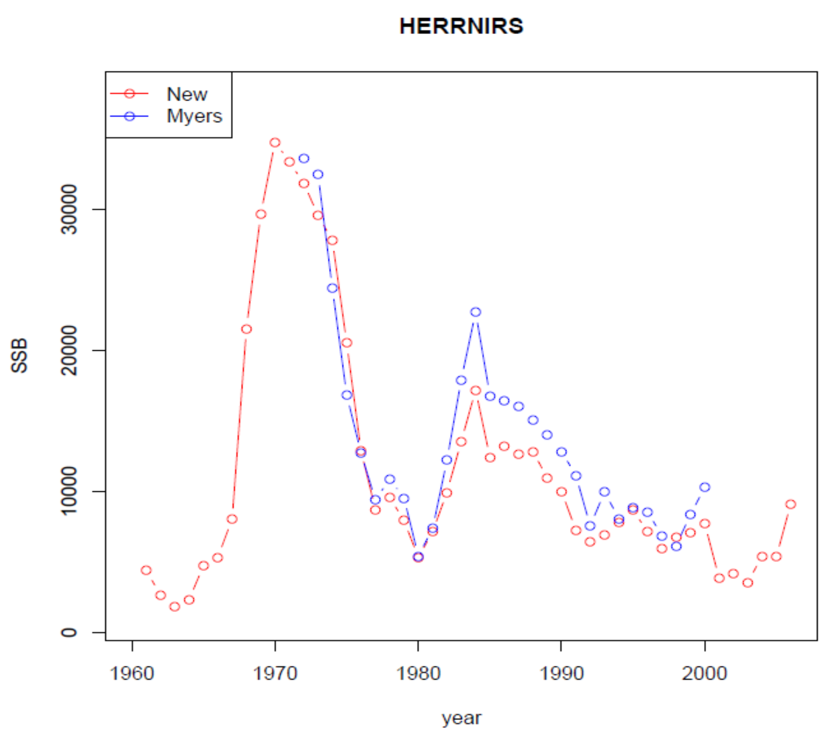
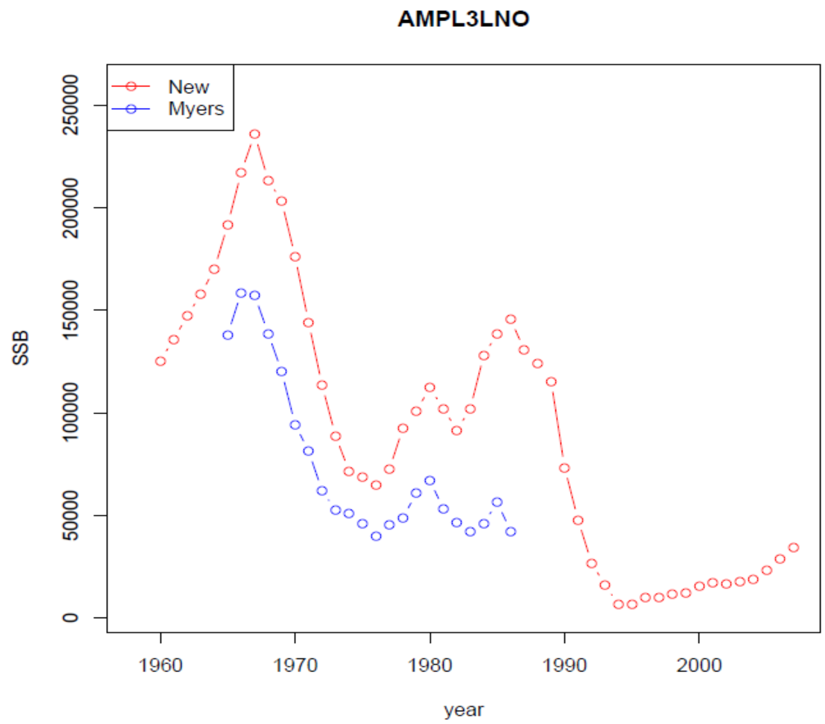
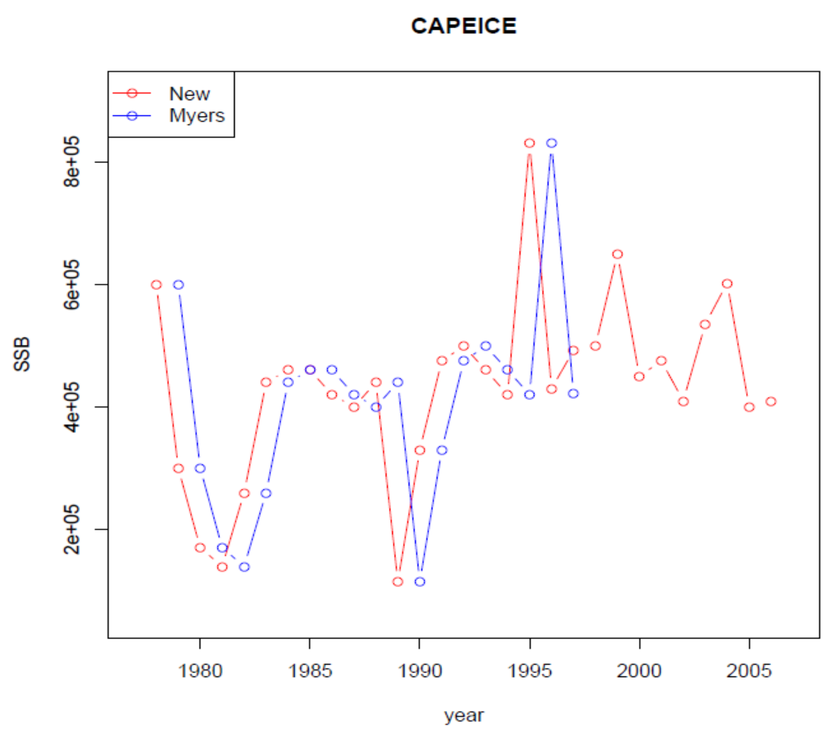


Figure 3: Plots showing the RAM I (blue) and RAM II (red) spawning stock biomass (in metric tonnes) time series for stocks whose truncations have concealed precedent in spawning stock biomass recovery or levels. a)haddock on the Rockall bank, b) herring in the northern Irish Sea, c)see Figure 1b, d) see Figure 1c, e)see Figure 1e

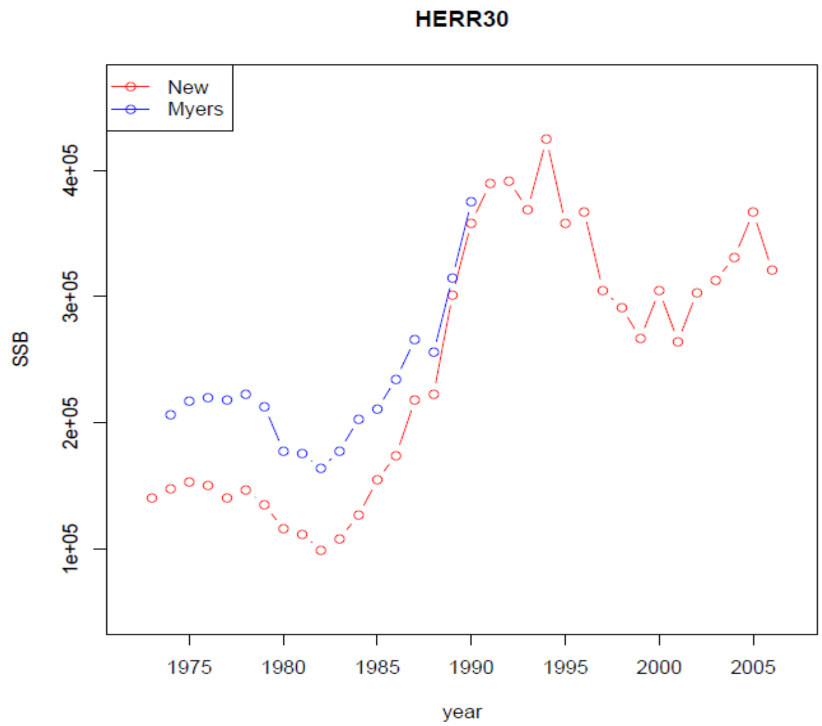
a)


AMPL3LNO
New
Myers
SSB
0
50000
100000
150000
200000
250000
1960
1970
1980
1990
2000
year

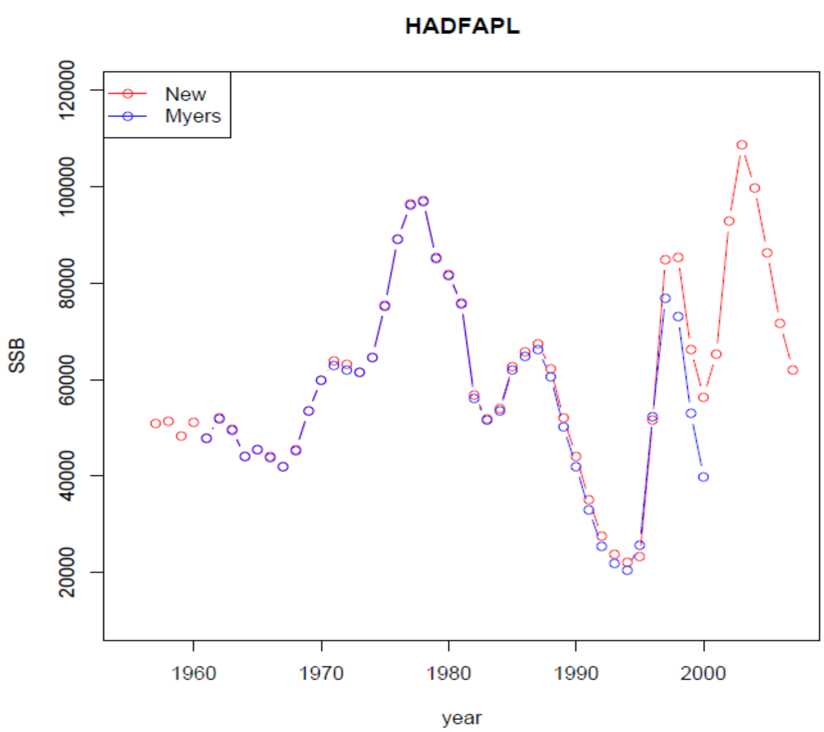
b)


CAPEICE
New
Myers
SSB
2e+05
4e+05
6e+05
8e+05
1980
1985
1990
1995
2000
2005
year

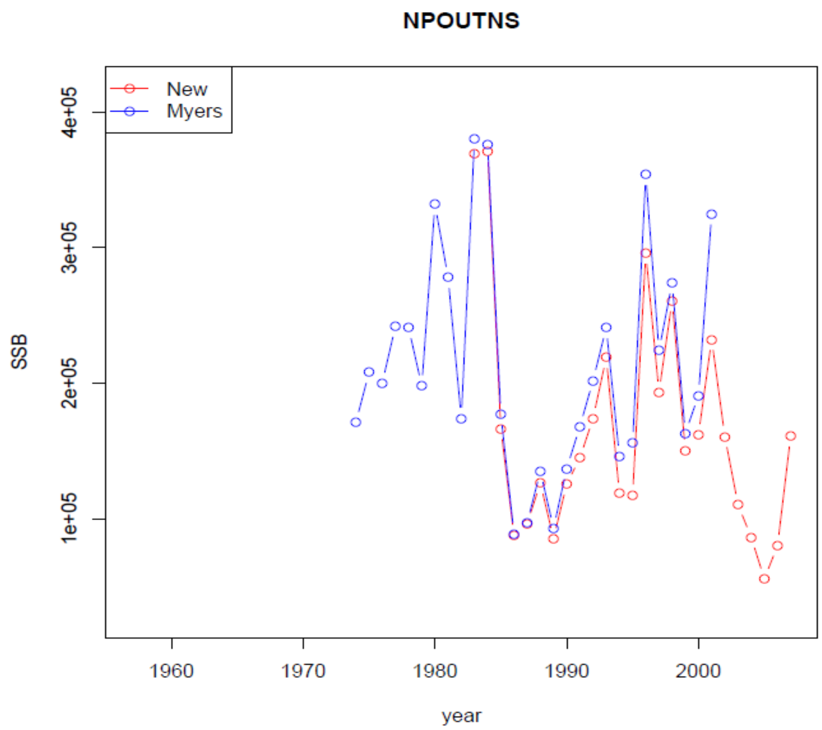
c)


HERR30
New
Myers
SSB
1e+05
2e+05
3e+05
4e+05
1975
1980
1985
1990
1995
2000
2005
year

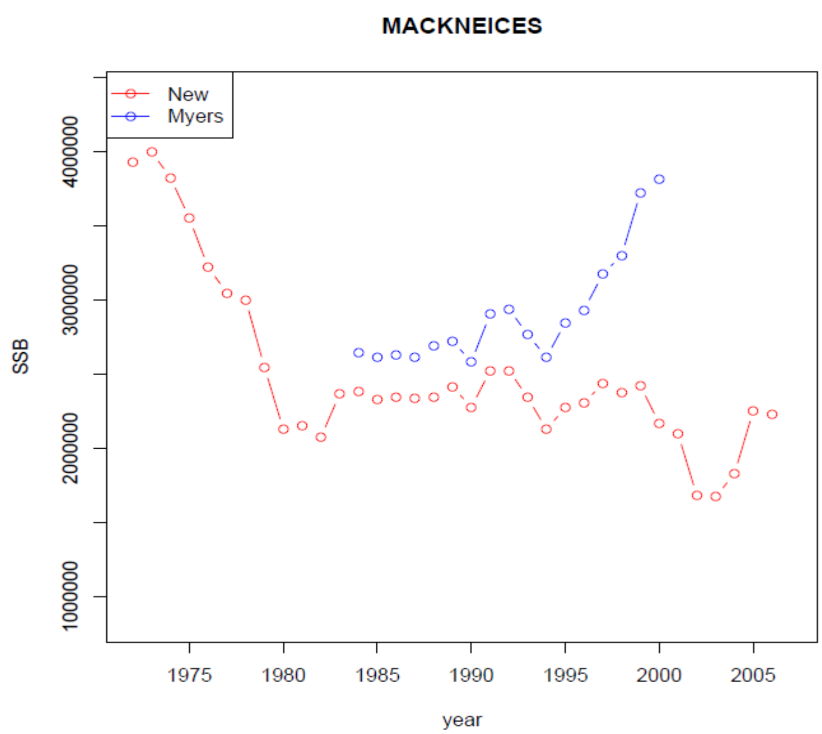
d)


HADFAPL
New
Myers
SSB
20000
40000
60000
80000
100000
120000
1960
1970
1980
1990
2000
year

e)


NPOUTNS
New
Myers
SSB
4e+05
3e+05
2e+05
1e+05
1960
1970
1980
1990
2000
year

f)


MACKNEICES
New
Myers
SSB
4000000
3000000
2000000
1000000
1975
1980
1985
1990
1995
2000
2005
year

g)

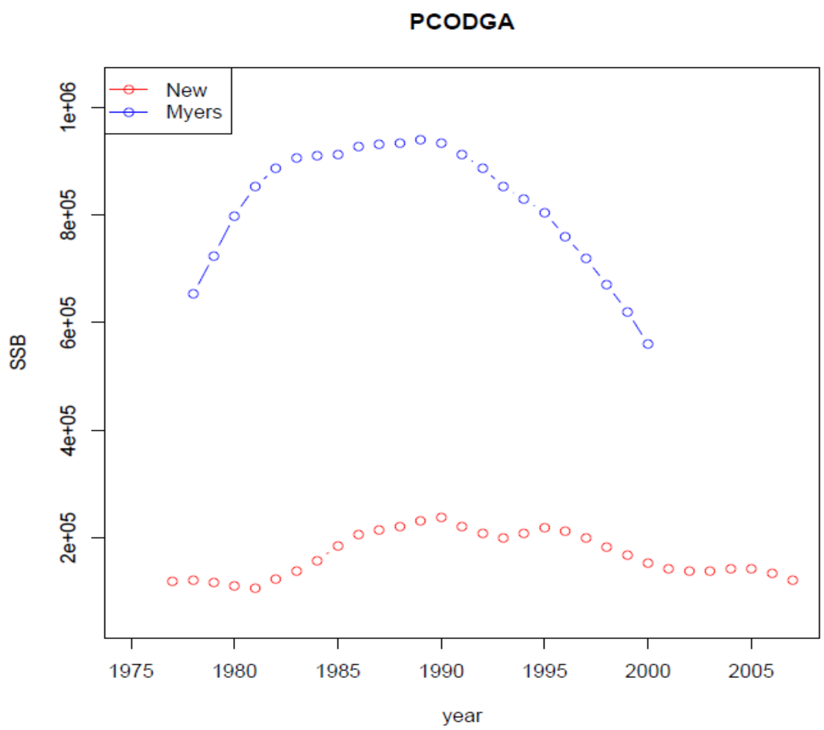


Figure 4: Plots showing the RAM I (blue) and RAM II (red) spawning stock biomass (in metric tonnes) time series for stocks whose truncation or lengthening has had no effect. a) American plaice in NAFO Division 3LNO, b) Icelandic capelin, c) Bothnian Sea herring, d) haddock on the Faroe Plateau, e) Norway pout in the North Sea f) mackerel in the north east Atlantic, g) Pacific cod in the Gulf of Alaska.

DISCUSSION

Shifting baselines in marine fisheries have been associated with an acceptance of progressively unhealthier fish stocks (Pauly 1995). Consequently the primary objective of this study was to determine if truncations of recent time series create shifting baselines. This was achieved through our secondary objectives which included quantifying the proportion of stocks assessments which were truncated, identifying the rationale behind these and to attempting to gain a better understanding of the effects that shifting baselines have on perceptions of stock status.

Truncation of years from the beginning of the most recent time series appeared to occur in roughly 32% of stocks (n=81). In another 19%, stocks assessments (n=81) additional years were added to the beginning of the most recent time series compared to the mid-1990's one. The truncations in the stocks which I investigated hid historical spawning stock biomass maxima in 67% of cases (n=9), concealed fluctuating patterns in 44% of cases (n=9) and camouflaged precedents in recoveries or spawning stock biomass levels in 44% of cases (n=9). The addition of years to the start of a time series had no effect on perceptions of stock health in 86% of lengthened cases (n=7). In one case only (14%, n=7) did the lengthening reveal a precedent in recovery.

Lengthened Stocks

In all instances of lengthening except one the modification did not cause any changes in perception of stock status. In most cases the lengthened time series based on the most recent assessments only extended 1 to 5 years beyond the mid-1990's time series. This is usually not enough of an addition to uncover any historic trends in spawning stock biomass which may be hidden. Only one of the two time series elongated by more than 5 years was affected by this change. This modification in the time series of herring from the northern Irish Sea exposed a precedent in current low spawning stock biomass levels and also indicated that the stock had managed to recover from these before.

In the case of herring in the Northern Irish Sea, the lengthening of its contemporary time series uncovered a previous extreme low in spawning stock biomass as well as a recovery from this. This shows how extending time series can possibly help with management. The years that have been added on to this time series, compared to that of the mid 1990's, show that the contemporary low levels have been seen before in this stock but also that since they have recovered from these before there is a chance that with proper management they could do so again. It also gives scientists the chance to investigate what was happening in the fishery and in the environment at that time to try to derive ways to help the stock recover.

There are two lengthened stocks for which the lack of effect may possibly be due to inaccurate data. This may have occurred as some stocks in the RAM II database have yet to be quality controlled. In the Icelandic capelin stock (Figure 4b); the two time series have the exact same abundances through the period where they both have data except that each data point is offset by one year from its identical counterpart. This could have occurred if the data was accidentally shifted by one year when entered in the database. Also, in the Gulf of Alaska Pacific cod stock, the spawning stock biomass of the two time series differs by at least 40 thousand metric tonnes. Two issues may have caused this. The model used to estimate the spawning stock biomass in the 1990's may have been found to be inaccurate and then modified to results in much lower levels or the units for the spawning stock biomass may have been entered incorrectly into the database.

Truncations

Contrary to the lengthened stocks, of which only one had been affected by the modification, the truncated stocks had only one stock which was not affected. Truncations in general make it impossible to identify the 'known' baseline of a stock. I use the term known baseline here because this would represent biomass levels when research on any one stock would have started; the true baseline on the other hand would be the biomass levels before humans started fishing, which is thought to have occurred hundreds if not thousands of years ago for many stocks/populations (Jackson et. al 2001). The baseline of a stock is usually what we perceive "healthy" to mean for a stock. Having this baseline cut off and a new one created distorts this perception of healthy. Truncations also seem to disguise spawning stock biomass maxima and, trends of fluctuation, as well as previous recoveries or low abundance levels. These effects all have the potential to be very serious. Hidden fluctuations and prior recoveries can lead to misunderstandings of stock dynamics and subsequently to improper management. Erroneous estimates of SSB_{max} make it impossible to identify the magnitude of changes undergone by a stock and thus give us a false impression of stock health.

These results indicate that truncating time series can indeed erase the baseline of a stock and could lead to major drawbacks in management and conservation initiatives.

The elements which are affected by the truncation of time series as well as numerous other elements such as reference points and recruitment are all used by management to make decisions on the quantity of fish which will be removed during the year. If these decisions are based on erroneous perceptions then they have a very high chance of being harmful to the stocks by setting higher TACs than can be supported by a stock. For declining stocks these same elements are used to decide on recovery targets which are biomass levels that should be reached for the stock to be safe again. Again if these decisions are based on erroneous perceptions then the stock could be led to recover to a size which is ineffectual in keeping the stock healthy and harvestable. It is also possible that maintained fallacious perception of stock health due to shifting baselines may eventually lead to stock collapses.

It is sometimes hard for us to remember that humans have been fishing for more than 35 000 years (Jackson *et al.* 2001). What is even harder is for us to come to grips with the fact that this means that we have been affecting marine ecosystems for just as long. In fact we usually seem to be more familiar with the end of Pleistocene extinctions than those which occurred in the last few centuries in our oceans (Jackson 2001). This difficulty we have in assimilating information from the past is where the shifting baseline syndrome originates from. This phenomenon is not limited to fisheries; it is also seen in marine ecosystems where people are increasingly losing sight of what a “pristine ecosystem” is. One example of this is the shifting baseline with respect to marine oil pollution (Ruiz 2004). This is a significant problem; one which will come to the forefront of ecological studies as its effects become exacerbated by the synergy between issues of biodiversity loss, increasing world population and food demand; and so it calls for the conception of new and innovative ways to incorporate important historical data into stock assessments of commercially exploited species.

REFERENCES

Baum, J.K. (2004) Shifting baselines and the decline of pelagic sharks in the Gulf of Mexico. *Ecol. Lett*. 7:135-145.

Beddington, J.R., Agnew, D.J., Clark, C.W. (2007) Current problems in management of marine fisheries. *Science*. 316:1713-1716.

Bjorndal, K.A., Bolten, A.B. (2003) From ghosts to key species: restoring sea turtle populations to fulfill their ecological roles. *Marine turtle newsletter*. 100:15-21.

Botsford, L.W., Castilla, J.C., Peterson, C.H. (1997) The managements of fisheries and marine ecosystems. *Science*. 277:509-515.

Hilborn, R. & Walters, C. (1992) *Quantitative Fisheries Stock Assessment: Choice, Dynamics & Uncertainty.* Chapman and Hill, New York.

Hilborn, R., Branch, T.A., Ernst, B., Magnusson, A., Minte-Vera, C.V., Scheuerell, M.D., Valero, J.L. (2003) State of the world's fisheries. *Ann. Rev. Ecol. Syst*. 28:359-399.

Hutchings, J.A., Myers, R.A. (1994) What can be learned from the collapse of a renewable resource? Atlantic cod, *Gadus morhua*, of Newfoundland and Labrador. *Can. J. Fish. Aquat. Sci*. 51:2126-2146.

Jackson, J.B.C., Kirby, M.X., Berger, W.H., Bjorndal, K.A., Botsford, L.W., Bourque, B.J., Bradbury, R.H., Cooke, R., Erlanson, J., Estes, J.A., Hughes, T.P., Kidwell, S., Lange, C.B., Lenihan, H.S., Pandolfi, J.M., Peterson, C.H., Steneck, R.S., Tegner, M.J., Warner, R.R. (2001) Historical overfishing and the recent collapse of coastal ecosystems. *Science*. 293:629-638.

Jackson, J.B.C. (2001) What was natural in the coastal oceans? *Proc. Natl. Acad. Sci. U.S.A.* 98(10):5411-5418.

McClenachan, L., Jackson, J.B.C, Newman, M.J.H. (2006) Conservation implications of historic turtle nesting beach loss. *Front. Ecol. Environ*. 4(6):290-296.

McClenachan, L. (2008) Documenting the loss of large trophy fish from the Florida Keys with historical photographs. *Conserv. Biol*. DOI:10.1111/j.1523-1739.2008.01152.x

Myers, R.A., Bridson, J.M., Barrowman, N.J. (1995) Summary of worldwide stock and recruitment data. *Can. Tech. Rep. Fish. Aquat. Sci*. 2024:327

Pauly, D. (1995) Anecdotes and the shifting baseline syndrome of fisheries. *Trends Ecol. Evol*. 10(10):430.

Pinnegar, J.K., Engelhard, G.H. (2008) The 'shifting baseline' phenomenon: a global perspective. *Rev. Fish. Biol. Fish*. 18:1-16.

Ruiz, J.M. (2004) Oil spills versus shifting baselines. *Mar. Ecol. Prog. Ser*. 282:307-309.

Rosenberg, A.A., Bolster, J.W., Alexander, K.E., Leavenworth, W.B., Cooper, A.B., McKenzie, M.G. (2005) The history of ocean resources: modeling cod biomass using historical records. *Front. Ecol. Environ*. 3(2):84-90.

Sáenz-Arroyo, A., Roberts, C.M, Torre, J., Cariño-Olvera, M., Enriquez-Andrade, R.R. (2005) *Proc. R. Soc. B*. 272 :1957-1962.

Sheppard, C. (1995) The shifting baseline syndrome (editorial). *Mar. Pollut. Bull*. 30(12):766-767.