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Assessment of the Potential for Recovery of Smooth Skate (*Malacoraja senta* Garman 1885) in the Funk Island Deep Designatable Unit

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

Decline in abundance and reduction in the extent of distribution have been observed in several Smooth Skate (*Malacoraja senta* Garman 1885) populations inhabiting Canadian waters, despite the absence of directed commercial fisheries for this species. The main concentration was centered in NAFO Div. 2J3K, in Funk Island Deep designatable unit (DU), until the 1980s, when it experienced a substantial and protracted decline in area of occupancy, as well as abundance of both juveniles and adults. Consequently, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has recommended that the Funk Island Deep population be designated as Endangered, As a result, Fisheries and Oceans Canada (DFO) has initiated a Recovery Potential Assessment (RPA) of the Funk Island Deep DU under Canada's *Species at Risk Act (SARA),* to be used in formulating and evaluating conservation and management strategies for this species in terms of risk of extinction. This document provides updates in survey indices and commercial removals of Smooth Skate in the Funk Island Deep DU, and employs a Bayesian surplus production model to project population response to differing levels of fishing mortality (F) over varying time periods.

Évaluation du potentiel de rétablissement de la raie à queue de velours (*Malacoraja senta* Garman 1885) dans l'unité désignable de la fosse de l'île Funk

RESUME

L'abondance et l'étendue de la répartition de plusieurs populations de raie à queue de velours (*Malacoraja senta* Garman 1885) des eaux canadiennes ont diminué, bien que cette espèce ne soit pas menacée par la pêche commerciale. La concentration principale se trouvait dans la division 2J3K (unité désignable de la fosse de l'île Funk) de l'Organisation des pêches de l'Atlantique Nord-Ouest jusqu'aux années 1980, soit lorsqu'elle a enregistré un déclin prononcé et prolongé quant aux facteurs d'aire d'occurrence et d'abondance des jeunes et des adultes. Par conséquent, le Comité sur la situation des espèces en péril au Canada (COSEPAC) a recommandé que la population de la fosse de l'île Funk soit désignée comme espèce en voie de disparition. Ainsi, Pêches et Océans Canada a réalisé une évaluation du potentiel de rétablissement de l'unité désignable de la fosse de l'île Funk, en vertu de la *Loi sur les espèces en péril* du Canada, afin d'élaborer et d'évaluer les stratégies de conservation et de gestion liées à l'espèce en question pour ce qui est du risque d'extinction. Le présent document révèle les mises à jour en matière d'indices d'abondance et de prélèvements par la pêche commerciale de la raie à queue de velours dans l'unité désignable de la fosse de l'île Funk et se sert d'un modèle bayésien de production excédentaire pour prévoir la réaction de la population envers les différents niveaux de mortalité par pêche au cours de diverses périodes.

INTRODUCTION

Declines in abundance and reduction in extent of distribution of Smooth Skate (*Malacoraja senta* Garman 1885, Family Rajidae) in the Northwest Atlantic Ocean have recently been reported in Canadian waters; including populations from the southern Gulf of St. Lawrence, Scotian Shelf, and in Newfoundland and Labrador (NL) waters (Simon et al. 2011, 2012; Simpson et al. 2011*a*). These declines have been observed despite an absence of directed commercial fisheries for this species, with removals limited to bycatch in fisheries targeting other species (Kulka 1986; Kulka et al. 2006; NOAA/NMFS 2000, 2009; Simpson et al. 2011*a*).

Vulnerability to exploitation, even when incidentally captured at low levels, has been documented for various elasmobranch species by Frisk et al. (2001); although not for Smooth Skate. Low reproductive potential resulting from slow growth, late sexual maturation, low fecundity, and long reproductive cycles is thought to lead to low resilience to fishing mortality (Hoenig and Gruber 1990; Smith et al. 1998; Musick et al. 2000; Musick 2004).

Recently, COSEWIC has assessed the status of Smooth Skate in Canadian waters (COSEWIC 2012). The Committee on the Status of Endangered Wildlife in Canada recommended that the Funk Island Deep DU of Smooth Skate be listed as Endangered, while the Laurentian-Scotian DU is considered to be of Special Concern. Two additional DUs, located in the Hopedale Channel and the Nose of the Grand Bank, were considered to be data deficient.

This paper updates the information provided for the COSEWIC assessment of Smooth Skate in the Funk Island Deep DU, to facilitate a RPA of this population, as required under Canada's *SARA.* It provides recent trends in abundance and distribution, as well as updated estimates of bycatch mortality from commercial fishery monitoring data. In addition, the paper provides stochastic projections of population biomass, using a Bayesian surplus production model, to facilitate the formulation of appropriate conservation and management actions to mitigate extinction risk.

ASSESSMENT

DISTRIBUTION, ABUNDANCE AND HABITAT ASSOCIATIONS

Surveys - NL Region

Bottom trawl research surveys have been conducted by DFO over the continental shelves of Newfoundland and Labrador in the fall (1977-2012, NAFO Div. 2J3K; NAFO Div. 3L was added in 1981) in the Funk Island Deep DU area. Surveys were originally designed to provide estimates of abundance for commercially important groundfish species, such as Atlantic Cod (*Gadus morhua*) and redfish (*Sebastes* sp.). However, Smooth Skate distributes in similar depth and latitudinal ranges, so the survey footprint adequately covers the distribution range of this species in this area.

Research surveys in the NL Region employ a random stratified design, with fishing tow allocation based on depth intervals and location (latitude and longitude). A summary of the survey design employed in NL waters since 1970 can be found in Doubleday (1981).

Fall surveys in Div. 2J3K were conducted by RV *Gadus Atlantica* until 1994. In 1995-2000, they were conducted mainly by RV *Teleost*; although RV *Wilfred Templeman* surveyed part of Div. 3K. Div. 3L surveys were conducted by RV *A.T. Cameron* (1971-82), and RV *Wilfred Templeman* or its sister ship RV *Alfred Needler*. An Engel 145 Hi-lift trawl was used for fall surveys from 1977 to 1994, and a Campelen 1800 shrimp trawl from 1995 to present. While survey design has remained constant, additional strata have been included in recent years; along with modifications to some of the original strata (Bishop 1994). One significant change in the surveys was the addition of shallower (< 50 m) and deeper strata (> 700 m) after 1993; although tows at depths < 50 m were occasionally recorded in earlier years. Additional causes of variation in survey coverage are discussed in detail by Brodie and Stansbury (2007), and Healey and Brodie (2009). It should be noted that no Smooth Skate conversion factors exist for the Engel to Campelen gear change; therefore, each time series must be considered independently.

Spatial Distribution and Habitat Associations

Geo-referenced catch and hydrographic data for the fall bottom trawl survey were used to assess the spatial distribution of Smooth Skate in the Funk Island Deep DU. Maps of the geographic distribution of catch rate (number/tow) were plotted using data from this survey, for each year from 2009-12.

Area of Occupancy

The area of occupancy (A_t) was calculated in each year t as follows:

$$A_t = \sum_{k=1}^{S} \sum_{j=1}^{N_k} \sum_{i=1}^{n_j} \frac{a_k}{N_k n_j} I \quad \text{where } I = \begin{cases} 1 \text{ if } Y_{ijkl} > 0 \\ 0 \text{ otherwise} \end{cases}$$

where Y_{ijkl} is the number of fish in length interval l caught in tow i at site j in stratum k, a_k is the area of the stratum k (km^2), N_k is the number of sites sampled in stratum k, n_j is the number of tows conducted at site j, and S is the number of strata.

Abundance Indices and Size Composition

Survey indices for the Funk Island Deep DU were expressed as mean fish number per standard tow, weight per standard tow, relative abundance and relative biomass. Since the fall survey footprint does not conform to Smooth Skate DU boundaries, survey areas were segmented to conform to DU locations: Div. 2J3K and a small portion of Div. 3L represents the Funk Island Deep DU. McPhie and Campana (2009*a*, 2009*b*) indicated that Smooth Skate < 48 cm and ≥ 48 cm Total Length (TL) roughly corresponded to the immature and mature components of the population, respectively. Therefore, where possible, estimation was also done separately for immature (< 48 cm) and mature (≥ 48 cm) skates, and indices were expressed as number per tow, and relative abundance.

SURPLUS PRODUCTION MODELLING

A Bayesian surplus production model was implemented in Winbugs with an R interface for this DU. See models for Roundnose Grenadier (Simpson et al. 2011*b*) and American Plaice (Bailey 2011; Morgan et al. 2011) for more details.

Biomass was modeled historically using estimated priors for K, r, and q (Table 1). Catch and stock biomass estimates from Canadian RV surveys were incorporated into the model as observed data with error.

WinBUGS (v.1.4.3), was used for all Bayesian Markov Chain Monte Carlo with Gibbs sampling models. WinBUGS was called from R (v.2.13.1) using the R2WinBUGS package. Convergence and model diagnostics were all run from R using the Bayesian Output Analysis (BOA) library. Models were run using 100000 iterations and a burn-in period of 40000 with thinning at 20 to reduce the possibility of autocorrelation within the series.

Data

The data from the Funk Island DU spanned 1981-2010, and included a gear change (Engel to Campelen). These data were not converted, and were used as separate series in the model, as indicated below:

- Canadian Autumn RV Survey Indices: Engel Series – 1981-94
- Canadian Autumn RV Survey Indices: Campelen Series – 1995-2012
- Landings Data: 2J3K - 1981-2012

Prior Distributions

Non-informative priors with relatively wide distributions were used for catchability (*q*), observation and process errors. Priors for observation error were limited to an upper bound at 3 times the CV for each index (Swain et al. 2009). The lower bound was set to zero. Sigma (process error) was allowed to vary between 0 and 1 (Table 1).

Vague priors were also used for carrying capacity (*K*) and the intrinsic rate of population increase (r; Table 1). Typically, *K* is set to the stock biomass in the year prior to the onset of fishing (P_0; Meyer and Millar 1999*a*). However, in the models used here, the stock biomass in 1981 was not assumed to be the virgin biomass. This may or may not have been the case but, since it is impossible to know for certain, P_0 was allowed to vary between 0.5 and 1 (i.e., initial biomass was allowed to vary between *K/2* and *K*).

A lognormal distribution for *K* was specified with a mean of 6000 t and a standard deviation of 3000 t and was limited to between 1000 t and 12000 t for this DU. The distribution was set to encompass a very wide range of possible values of *K* while remaining semi-informative. The mean estimate was based on the survey data (~2000 t higher than the highest historical estimate) while allowing an extremely wide distribution.

Similarly, the prior for *r* was set using a mean with a wide lognormal distribution. For this DU, *r* was set at μ=0.2 and std=0.15, and restricted to values between 0.001 and 3.0. All prior distributions are given in Table 1, with posterior results in Table 2.

REFERENCE POINTS

Under the DFO Precautionary Approach (PA) framework, the Critical, Cautious, and Healthy stock status zones are defined by the Limit Reference Point (LRP) and an Upper Stock Reference (USR). In situations where there is insufficient information to determine stock biomass from an analytical model, an empirical approach can be used to identify proxies that are appropriate to defining PA reference points. For Smooth Skate, a BMSY proxy (biomass giving maximum sustainable yield) was derived from the DFO fall multispecies RV survey series (1981-2012). Empirically derived reference points were based on the geometric mean of 1981-88: a period of higher productivity.

COMMERCIAL FISHERIES REMOVALS

Fisheries data available in the NL Region include the Newfoundland Fisheries Observer Program (NFOP) database, which contains set-by-set information collected at sea in a standardized format by trained Canadian Fisheries Observers. NFOP Smooth Skate bycatch data from 2000-12 were used; albeit length frequencies were never collected from Div. 2J3K. A second source of fisheries data was the DFO-NL Zonal Interchange Format (ZIF) database, created in 1985 to record commercial landings reported by Canadian fishers (as recorded in their logbooks and on fish plants' purchase slips). It must be noted that bycatch of non-commercial species and discards (even of target species) are never reported to DFO-NL Statistics Branch (for ZIF), nor to the Northwest Atlantic Fisheries Organization (for NAFO databases). Therefore, NFOP data constitutes the only reliable source of bycatch of non-commercial species and discarding at sea.

To estimate total bycatch of Smooth Skate in various Div. 2J3K fisheries, a method based on Kulka et al. (2006) was used with the NFOP and DFO-NL ZIF databases for 2000-12. For each fishery, reported landings of the target species (in ZIF-NL; summed by year) by fishing vessel size category was divided by the observed kept weight of this target species per vessel category by year (e.g., Greenland Halibut, *Reinhardtius hippoglossoides*; Northern and Striped Shrimp, *Pandalus borealis* and *P. montagui*; Atlantic Cod, *Gadus morhua*). This factor was then multiplied by the observed catch weight (=kept+discards) of Smooth Skate per vessel category in each fishery by year; in order to "bump up" this species' bycatch estimates to the entire fishery. Although this method proved useful, very low to no Observer coverage of certain fisheries precluded its application to particular years or to low/no-coverage fisheries in Div. 2J3K. Therefore, total removals of Smooth Skate could not be estimated for every fishery conducted in Div. 2J3K.

To estimate relative fishing mortality, the ratio of estimated commercial landings (all fisheries combined) to research survey biomass estimates was calculated for each year over 2000-12.

RESULTS AND DISCUSSION

DISTRIBUTION AND HABITAT ASSOCIATIONS

Survey Catch Distribution

Recent fall survey catch rates (2009-12) in the Funk Island Deep DU are shown in Figure 1, and are consistent with previous time periods (see Simpson *et al*. 2011a). Higher catch rates occurred in deeper troughs adjacent to Hamilton Bank, Belle Island Bank, and the Funk Island Bank. Smooth Skate are often found in deeper and broader water layers (200-600 m) in this DU, and are infrequently recorded in tows below 800 m. Smooth Skate were also found over a similar range of water temperatures throughout the Funk Island Deep DU, and over the entire survey time series. In Div. 2J3KL, Smooth Skate are most often captured in waters ranging from 1.3 ˚C to 3.5 ˚C (Simpson et al. 2011).

As previously established (Kulka et al. 2006; Simpson et al. 2011*a*), Smooth Skate appear to be temperature seekers, and are constrained geographically by the availability of suitable temperature habitats. Densest concentrations of this species occur in troughs surrounding the banks, where water temperatures are warmer.

Area of Occupancy

In the Funk Island Deep DU in the fall, area of occupancy peaked in 1982 when Smooth Skate were found in 38 % of the survey area, but subsequently steadily declined to < 2 % by the year 2000. Over the last decade, area of occupancy generally increased, reaching an average of 7.7 % over 2007-12 (Fig. 2). The estimate of A_t in 2012 was 5.9 %.

ABUNDANCE

Catchability of skate species (including Smooth Skate) by research bottom trawls has been considered low, given the bottom-dwelling nature of this group. Skates of all sizes have been observed to flatten into the substrate when fishing gear approaches, and escape under the trawl's footrope. Consequently, indices from bottom trawl surveys likely underestimated the presence of Smooth Skate to a large extent. It should be noted that previous comparisons of catch by Engel and Campelen trawls prior to, and immediately after, the survey gear change in 1995 suggested that catchability was higher for all size classes with the Campelen trawl. The Engel trawl captured almost no skates < 26 cm, while the Campelen frequently caught skates in that size range. Therefore, catchability of small Smooth Skate (< 26 cm) between both trawl types cannot be compared using available survey data. Hence, estimates of biomass and abundance presented in this paper must be viewed as minimum values. In addition, estimates of survey catch rate and abundance for this species in the periods prior to and post-gear change are on different scales.

For all size classes combined, mean number per tow (Fig. 3), and mean weight per tow (Fig. 4) declined precipitously through the Engel survey period. Similar trends were observed for estimates of relative abundance (Fig. 5) and relative biomass (Fig. 6). From 1995 to present (Campelen surveys), indices have varied without trend, and remained low. Both mean number per tow and relative abundance peaked in 2010, before declining to values similar to those observed for 1995-2009.

In the Funk Island Deep DU, Engel catch rates displayed similar temporal patterns for immature and mature Smooth Skate, in addition to relative abundance, but Campelen catch rates were higher for immature skates (Figs. 7 and 8). Mean catch rates in this DU (Engel surveys) peaked in 1983 for both immature (0.4 fish/tow) and mature (0.6 fish/tow) skates; then declined in both cases to relatively low values until 1994 (< 0.03 fish/tow). Catch rates remained at similar levels throughout the Campelen surveys (1995 onwards).

Abundance estimates of immature and mature Smooth Skate in the Funk Island Deep DU declined through the 1980s and early 1990s (Engel surveys), remained relatively low and stable through the mid-1990s to early 2000s (Campelen surveys); then abundance of immature Smooth Skate began to increase in recent surveys (Fig. 8). Abundance peaked at approximately 1.9 million immature (1983) and 2.7 million mature (1983) Smooth Skate, then declined to 0.14 million immature and 0.04 million mature (1994) individuals just prior to the survey gear change. Campelen survey estimates for both immature and mature components of the population in this DU have varied without trend from 1995 to 2009, averaging 380,000, and 90,000 individuals, respectively.

SURPLUS PRODUCTION MODELLING

Overall, diagnostics showed a relatively good fit for the model, with good convergence and reasonable posterior distributions (Table 2). However, concerns with respect to the accuracy of the landings data used in the model, and the unusually large process error (twice the observation error), resulted in rejection of the model for Smooth Skate in the Funk Island Deep DU. Further results or projections are therefore not presented.

REFERENCE POINTS

A BMSY proxy (biomass giving maximum sustainable yield) was derived from the DFO fall multispecies RV survey series (1981-2012). The empirically derived reference points were based on the geometric mean of 1981-88 RV survey series biomass estimate which was considered a period of higher productivity.

The default PA reference points calculated were 40 % BMSY (LRP) and 80 % BMSY (USR) (Fig. 9). The recent stock size averaged 18 % of the limit reference point over 2008-12 (Fig. 10).

COMMERCIAL FISHERIES REMOVALS

Although total mortality was high during the period of decline, it is not possible to determine sources of this mortality. No directed fishery for Smooth Skate has occurred in Newfoundland and Labrador waters. However, bycatch estimates of Smooth Skate in various Canadian 2J3K fisheries over 2000-12 suggest that commercial removals of this species in this DU are low. For fisheries with Observers' data, the Greenland Halibut (turbot) fixed gillnet fishery using 0-149.9 t vessels caught 0.9-3 t of Smooth Skate over 2000-03 and 5 t in 2010, with negligible amounts in the remaining years (Fig. 11). The Greenland Halibut bottom trawl fishery, using 150-2000+ t vessels, bycaught 0-0.4 t of this species; while the Northern Shrimp fishery, with 0-149.9 t vessels and trawl-mounted groundfish excluders (i.e., Nordmore grate), caught 0-0.5 t of Smooth Skate during this period. Bycatch of this species appeared negligible in the Northern Shrimp fishery using 150-2000+ t vessels and groundfish excluders, and also in the Snow Crab (*Chionoecetes opilio*) pot fishery. Overall, relative fishing mortality, calculated as the ratio of estimated commercial landings to estimated research survey biomass, averaged 0.0085 over 2000-12 (Fig. 12).

CONCLUSION

Extensive declines in abundance and area of occupancy were observed for both juveniles and adults in the Funk Island Deep DU during the 1980s and 1990s. However, this DU has shown some stability since the mid-2000s, with modest increases in area of occupancy in recent years.

The period of decline in the Funk Island Deep DU corresponds to the coldest water temperatures in this area (Colbourne et al. 2006). In addition, a comparison of rates of decline in areas of intense commercial trawling with those in areas of no trawling indicated no difference in decline rates of relative abundance of Smooth Skate (Kulka et al. 2006). Although commercial fishing removals may have contributed to population decline for this species, the lack of recovery during the 1990s following a warming period, plus apparently low fishing pressures observed since the late 1990s, suggests that factors other than fishing are driving the dynamics of Smooth Skate populations in Newfoundland and Labrador waters.

A BSP was fit to the data from the Funk Island Deep (1981-2010). BSP model diagnostics and fit to the survey indices appear to be reasonable for both time series over 1981-2010. In addition, there is no trend in process error in the model. However, there is sufficient process and observation error in the model to limit the use of long term projections, as indicated by the very wide credible intervals in the model projections.

SOURCES OF UNCERTAINTY

Several aspects of the current assessment of Smooth Skate in the Funk Island Deep DU remain uncertain; largely due to partial knowledge about population structure, dynamics, and biology. Hence, interpretation of the results in this paper should be undertaken judiciously.

Inclusion of new sampling strata and changes in gear type (and selectivity by fish size) in different survey periods make it difficult to assess spatial and temporal trends in abundance and distribution, the relationship between spawning population and recruits, and changes in survival, growth rate, and age structure over more than a few generations.

In addition, information on threats related to commercial fisheries was recently limited by low Observer coverage of only several fisheries for this DU, with no length frequencies collected at sea; thereby rendering it difficult to estimate the impact of bycatch mortality on abundance and population structure.

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Table 1 Priors for parameters used in the surplus production model for Smooth Skate

Parameter	**Description**	**Prior Distribution**
K	Carrying Capacity	LN (μ=6000t, sd=3000t)
r	Population growth rate	LN (μ=0.2, sd=0.15)
q.eng	Catchability, Engels Trawl Series	Norm(1,0.25)
q.cam	Catchability, Campelen Trawl Series	Norm(1,0.25)
Sigma	Process error	U(0,1)
tau.eng	Observation error, Engels Trawl Series	U(0,2.39)
tau.cam	Observation error, Campelen Trawl Series	U(0,1.99)

Table 2 Summary of parameter estimates using a Bayesian surplus production model for Smooth Skate in the Funk Island Deep DU

Parameter	**Description**	**Posterior (median, 95% CI)**
K	Carrying Capacity	4749.00 (2189.87 – 10070.25)
r	Population growth rate	0.10 (0.03 – 0.28)
q.eng	Catchability, Engels Trawl Series	0.69 (0.35 - 1.38)
q.cam	Catchability, Campelen Trawl Series	1.03 (0.49 – 2.12)
Sigma	Process error	0.61 (0.38 – 0.89)
tau.eng	Observation error, Engels Trawl Series	0.32 (0.02 – 0.76)
tau.cam	Observation error, Campelen Trawl Series	0.36 (0.03 – 0.80)
MSY	Maximum Sustainable Yield	120.45 (32.39 – 411.00)
F_{MSY}	F at MSY	0.05 (0.02 – 0.14)
B_{MSY}	Biomass at MSY	2374.00 (1094.95 – 5034.17)
DIC	Deviance Information Criteria	333.8

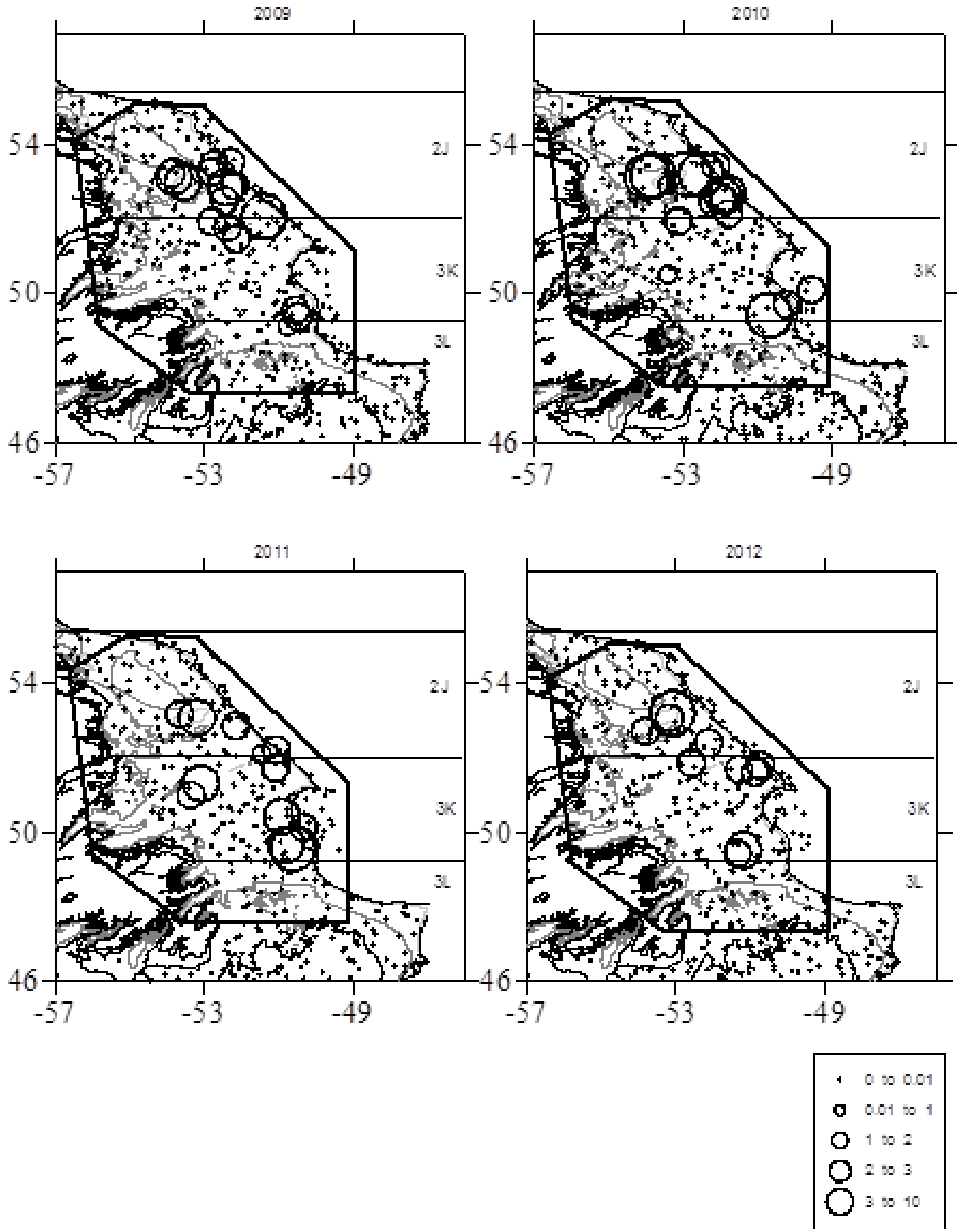


Figure 1 Numbers per tow of Smooth Skate caught in DFO fall research surveys conducted in the Funk Island Deep DU, 2009-2012

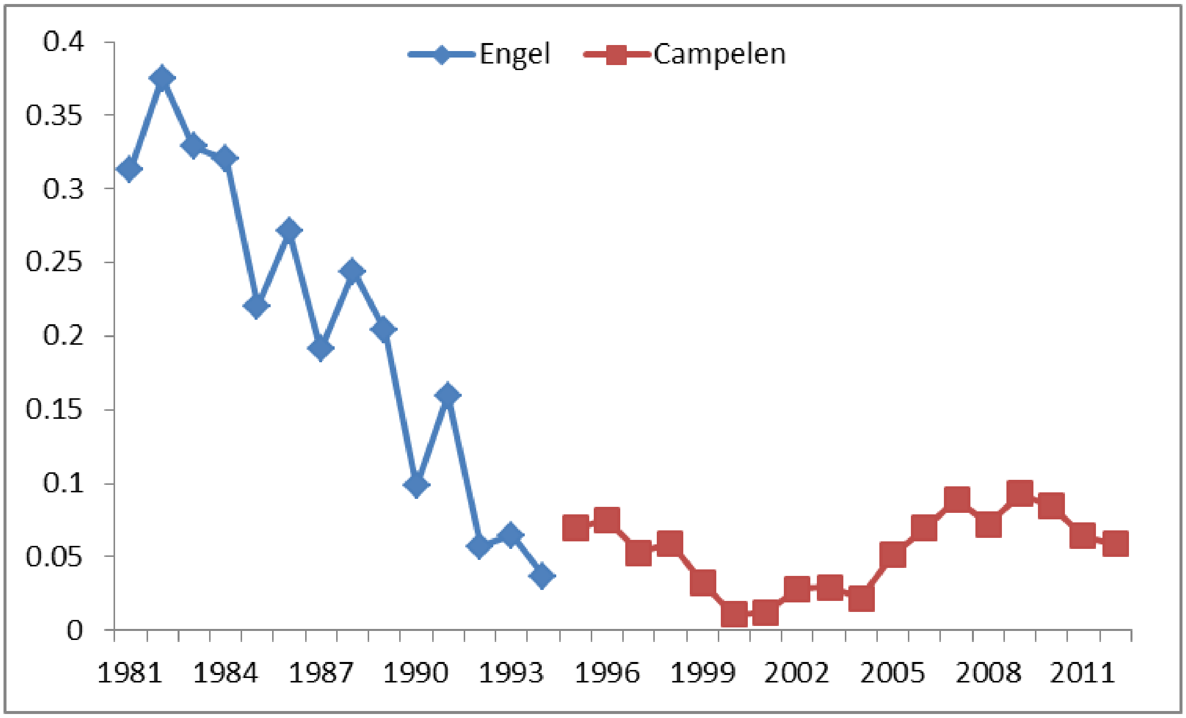


Figure 2 Area Occupied by Smooth Skate in DFO fall research surveys in the Funk Island Deep DU, 1981-2012. Note the change in survey gear from Engel to Campelen trawl in 1995

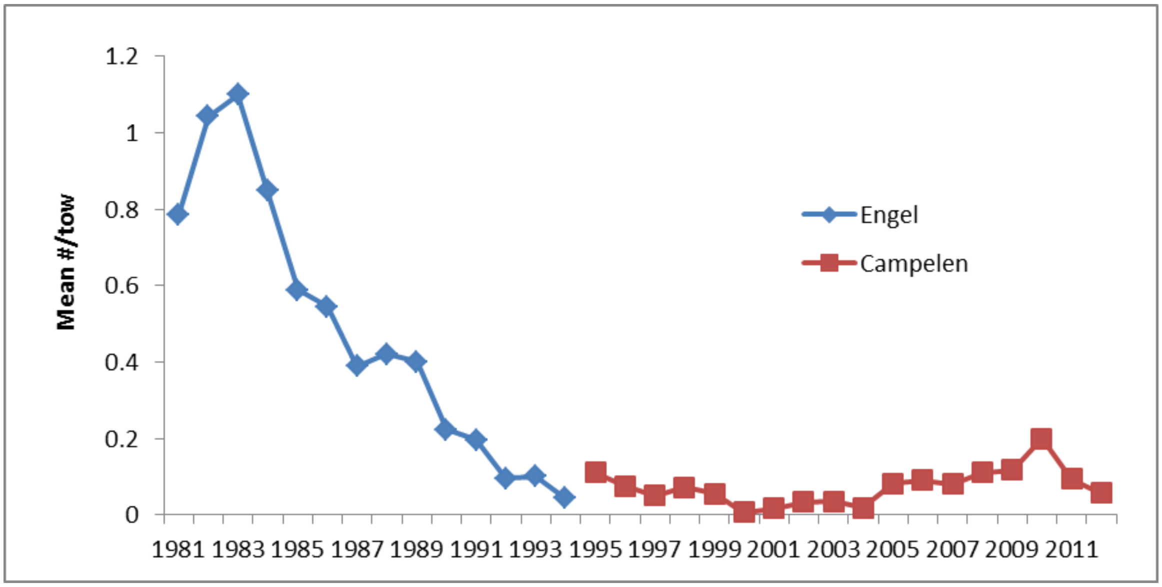


Figure 3 Mean number per tow of Smooth Skate in DFO fall research surveys in the Funk Island Deep DU, 1981-2012. Note the change in survey gear from Engel to Campelen trawl in 1995

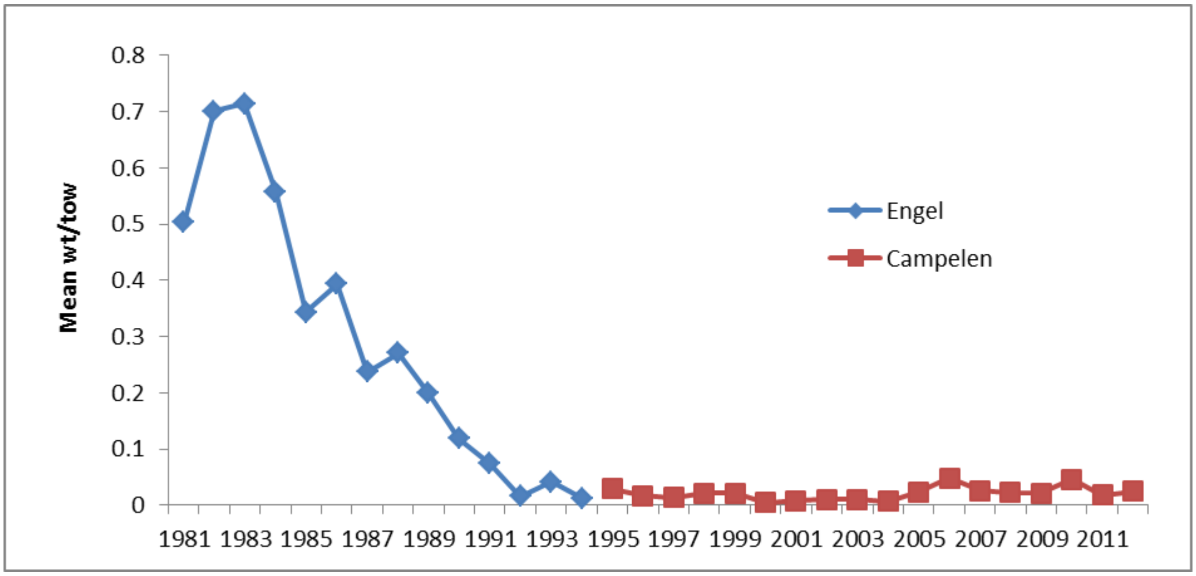


Figure 4 Mean weight per tow (kg) of Smooth Skate in DFO fall research surveys in the Funk Island Deep DU, 1981-2012. Note the change in survey gear from Engel to Campelen trawl in 1995

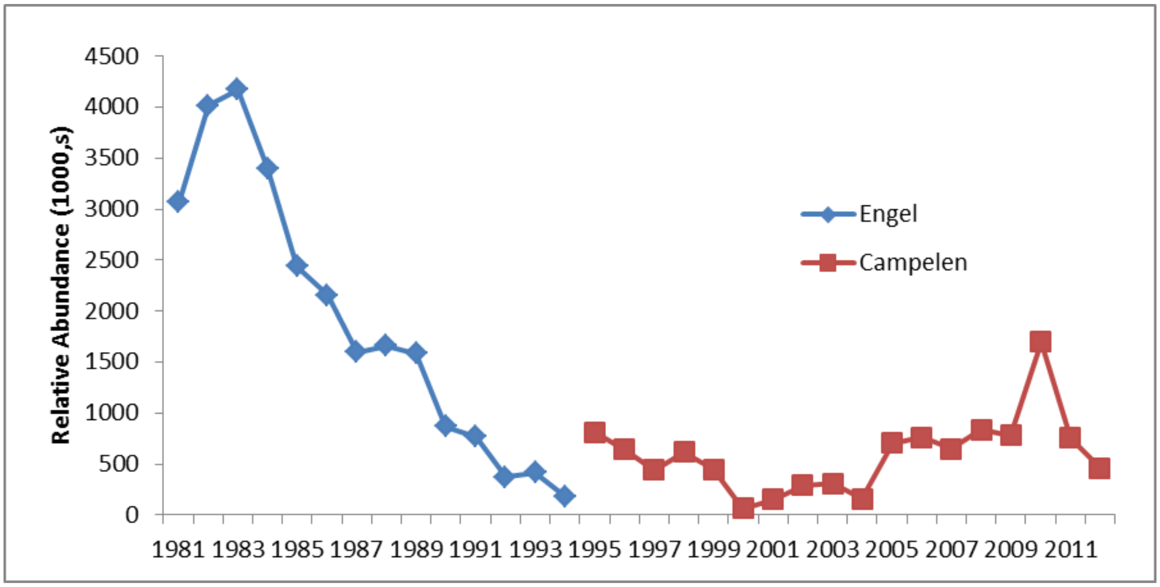


Figure 5 Abundance index for Smooth Skate in DFO fall research surveys in the Funk Island Deep DU, 1981-2012. Note the change in survey gear from Engel to Campelen trawl in 1995

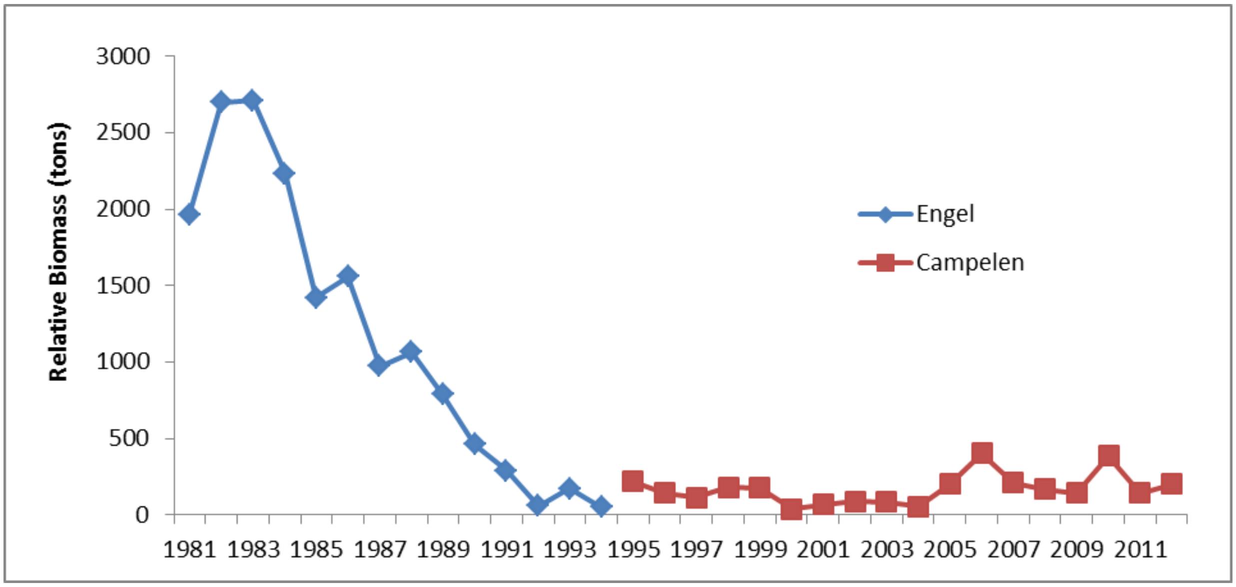
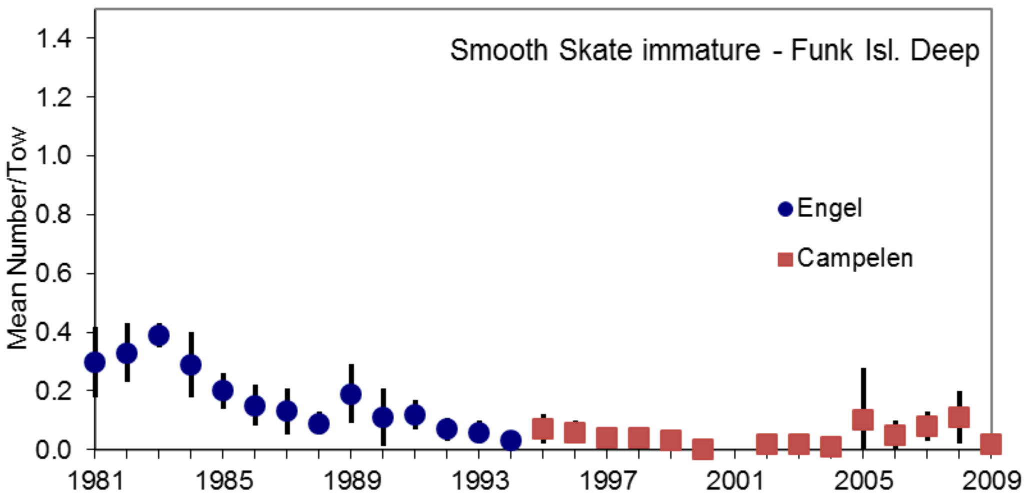


Figure 6 Biomass index (tons) for Smooth Skate in DFO fall research surveys in the Funk Island Deep DU, 1981-2012. Note the change in survey gear from Engel to Campelen trawl in 1995



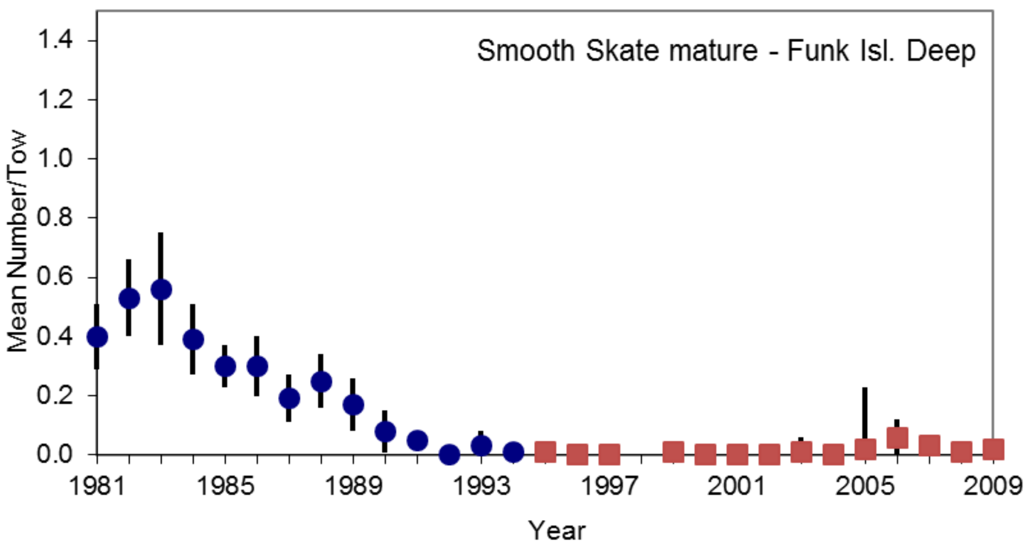


Figure 7 Mean number per tow of immature (< 48 cm) and mature (≥ 48 cm) Smooth Skate in DFO fall research surveys in the Funk Island Deep DU,1981-2009. Sampling by size was not conducted in 2010-12

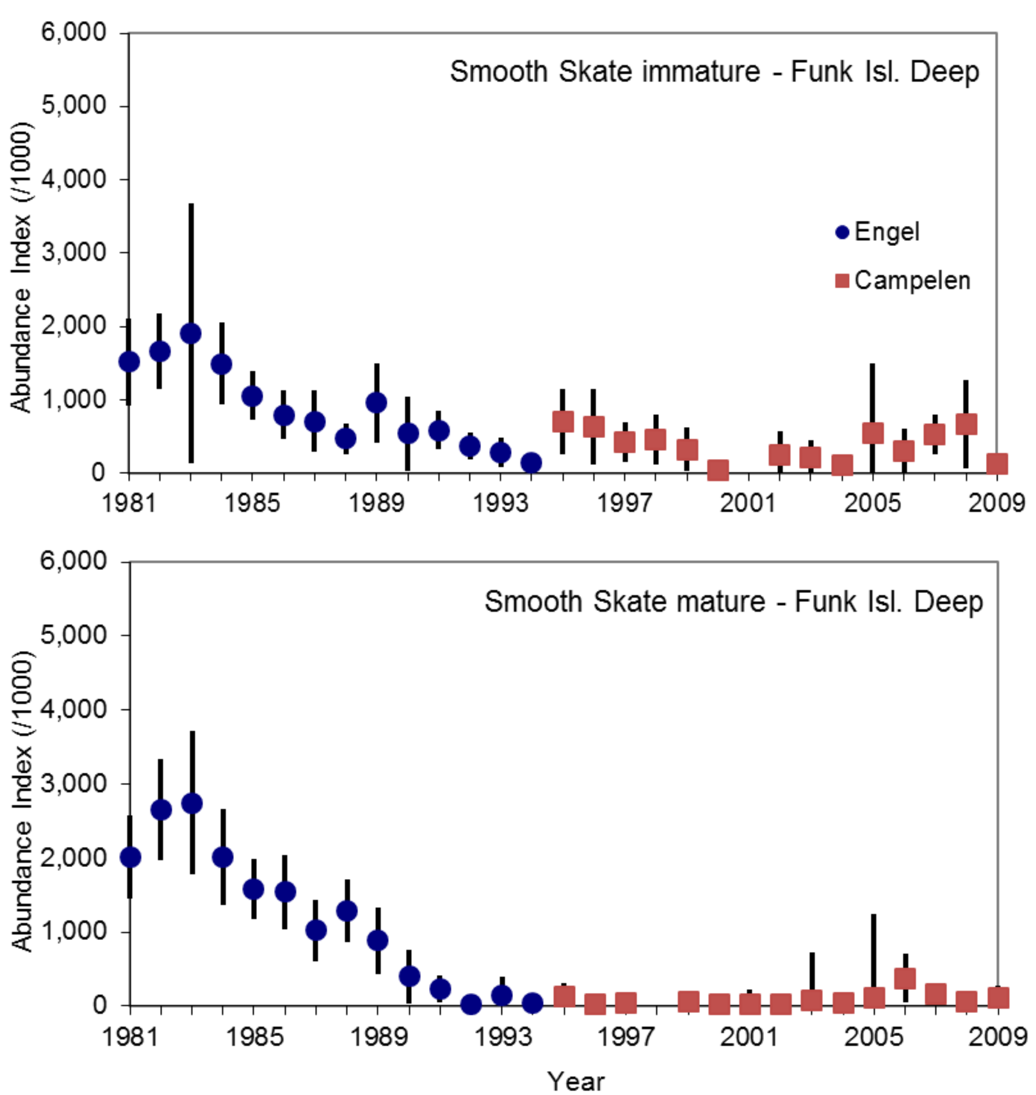


Figure 8 Index of abundance (000s) of immature (< 48 cm) and mature (≥ 48 cm) Smooth Skate in DFO fall research surveys in the Funk Island Deep DU, 1981-2009. Sampling by size was not conducted in 2010-12

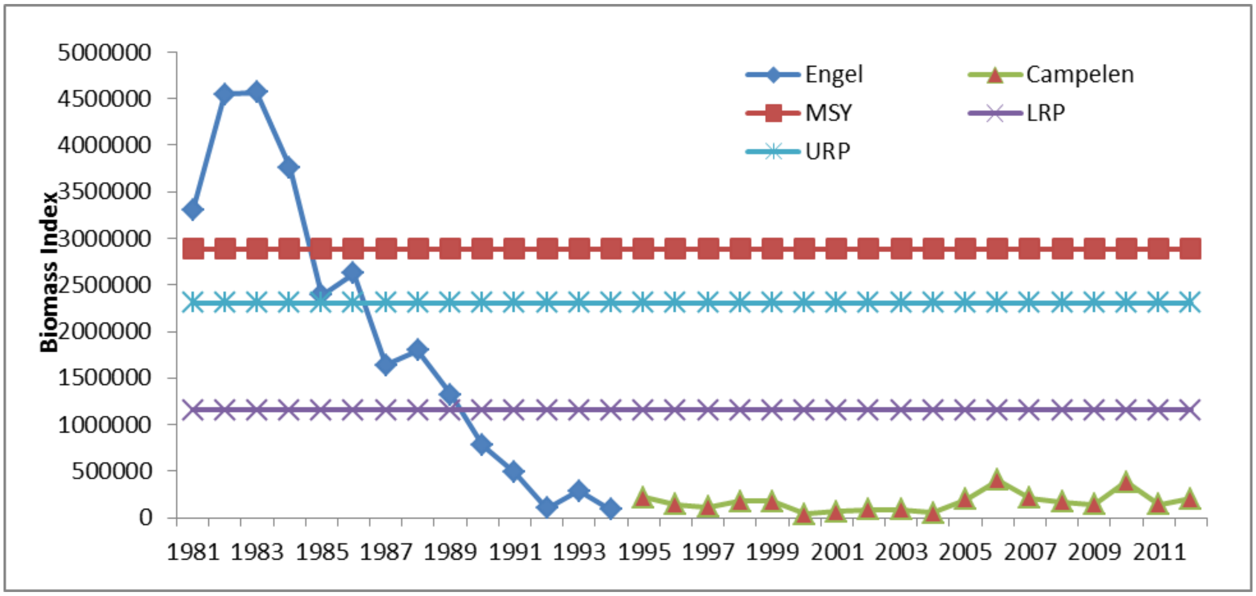


Figure 9 Plot of the B_{MSY} proxy and proposed PA reference points for Smooth Skate in the Funk Island Deep DU. Unit for biomass index is tonnes. Note the change in research survey gear from Engel to Campelen trawl in 1995

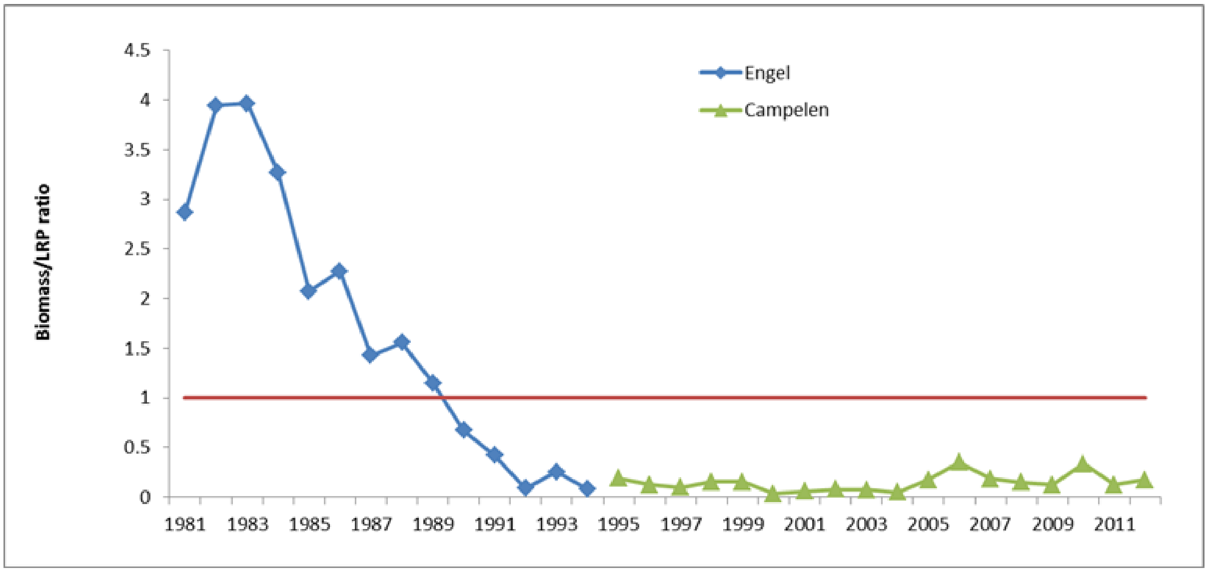


Figure 10 Plot of Biomass relative to the LRP for the Funk Island Deep DU. Note the change in research survey gear from Engel to Campelen trawl in 1995

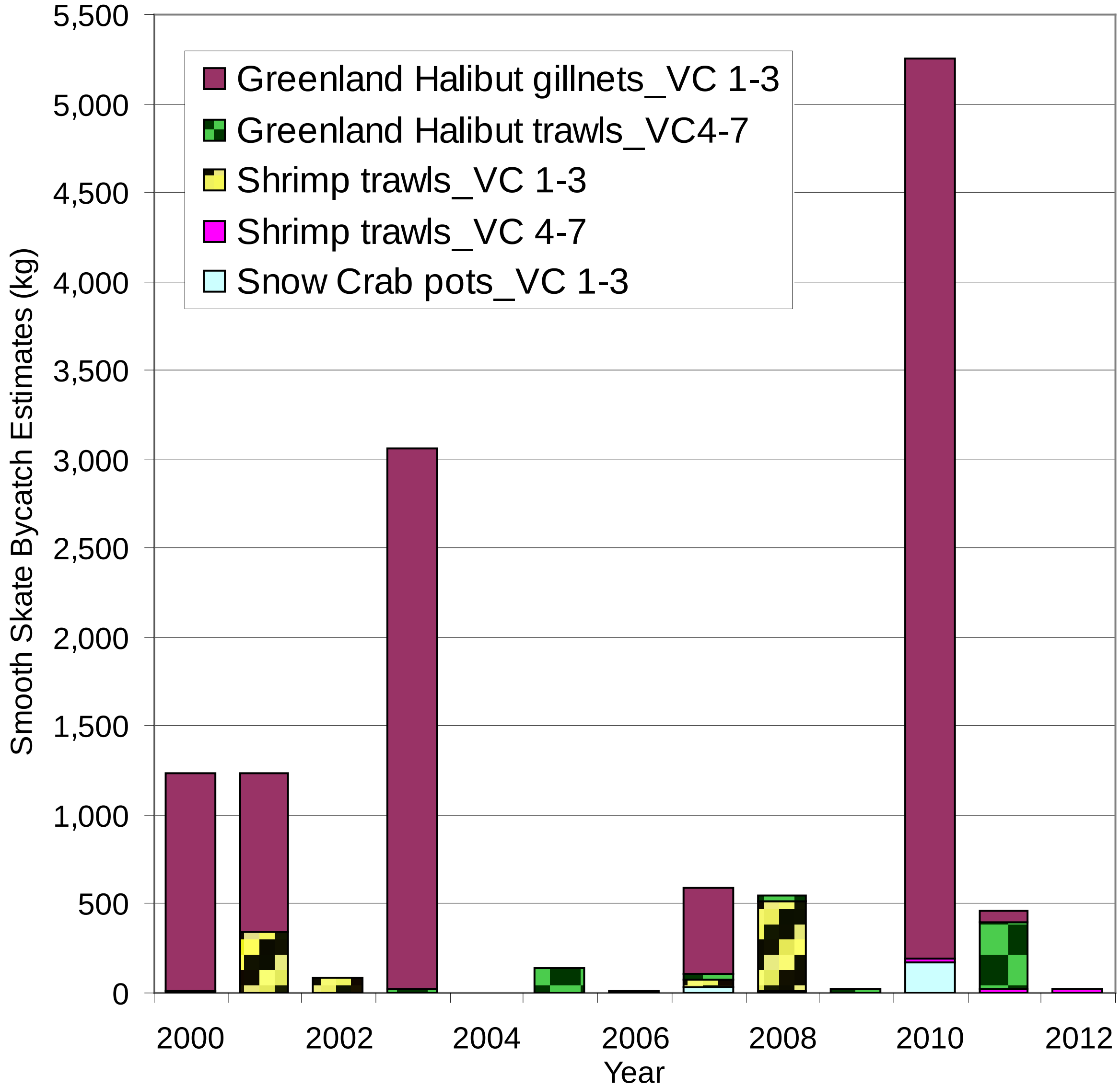


Figure 11 Bycatch estimates (kg) of Smooth Skate by observed fishery in the Funk Island Deep designatable unit, 2000-12. Data are from Canadian Fisheries Observers and DFO-NL ZIF

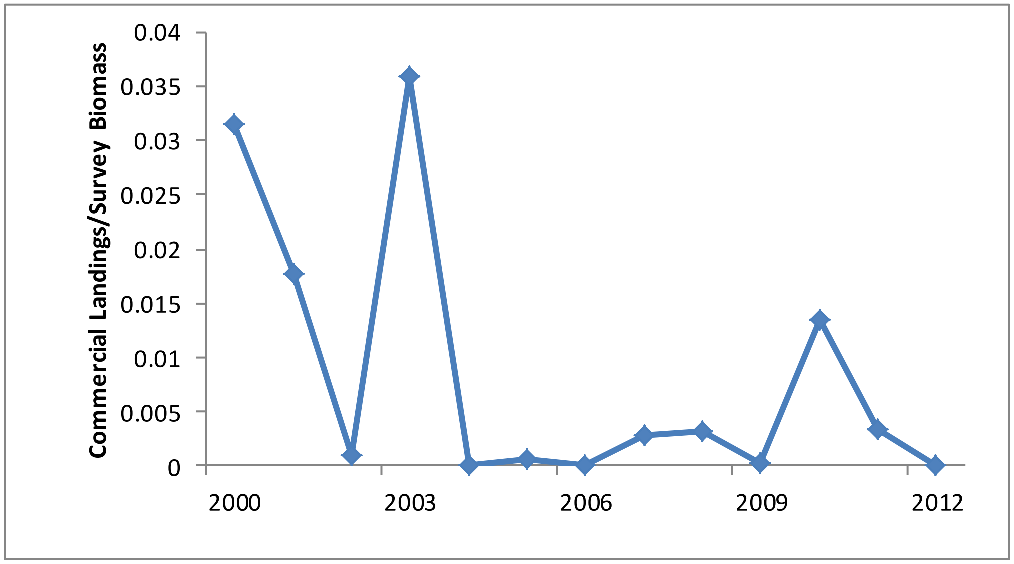


Figure 12 Relative fishing mortality estimates (commercial fishery landings relative to research survey biomass) in the Funk Island Deep designatable unit, 2000-12