The following supplement accompanies the article

Patterns of extirpation. I. Changes in habitat use by thornback rays *Raja clavata* in the German Bight for 1902–1908, 1930–1932, and 1991–2009

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Supplement. Supporting information on the location of shrimp and *Nephrops* feeding grounds (Figs. S1 & S2), the coastal shrimp fisheries modeled for 1933 (Fig. S3), the thornback ray surplus production model (Text S1), and the age structure of the survey catches (Table S1).

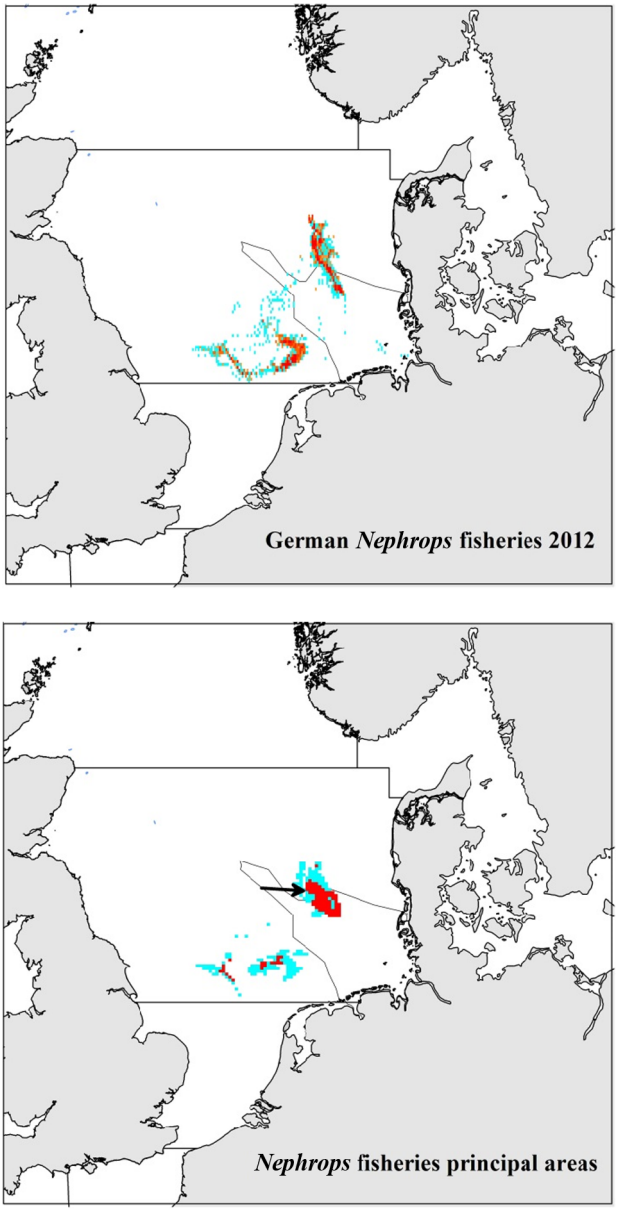

Fig. S1. *Nephrops* fishing grounds in 2012 and the principal fishing area in the NW German Bight as potential feeding areas for thornback rays *Raja clavata* (red part, indicated by arrow in lower panel). Colors represent an intensity scale (red = high). German EEZ indicated by thin gray line, as well as boundaries of the ICES areas in the North Sea. Principal fishing areas are multi-annual composites representing core areas with 75 % of the effort of the fisheries (Fock 2008)

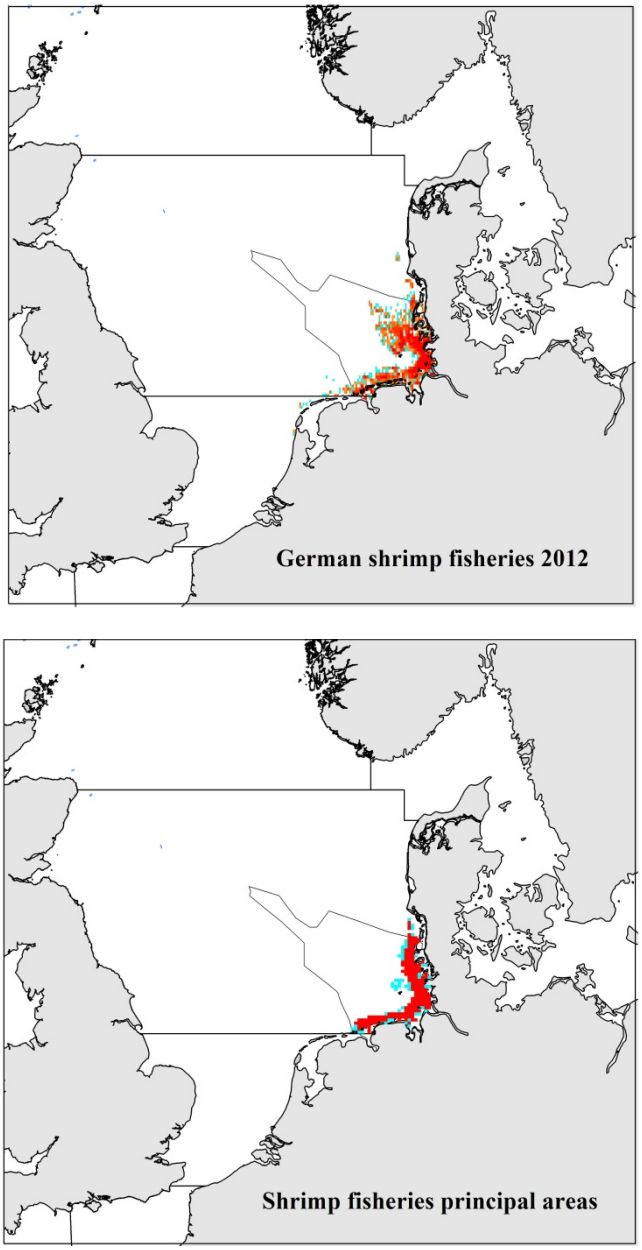

Fig. S2. German shrimp fishing grounds in 2012 and the principal fishing area in the NW German Bight as potential feeding areas for thornback rays *Raja clavata* (red in lower panel). Colors represent an intensity scale (red = high). German EEZ indicated by thin gray line, as well as boundaries of the ICES areas in the North Sea. Principal fishing areas are multi-annual composites representing core areas with 75 % of the effort of the fisheries (Fock 2008)

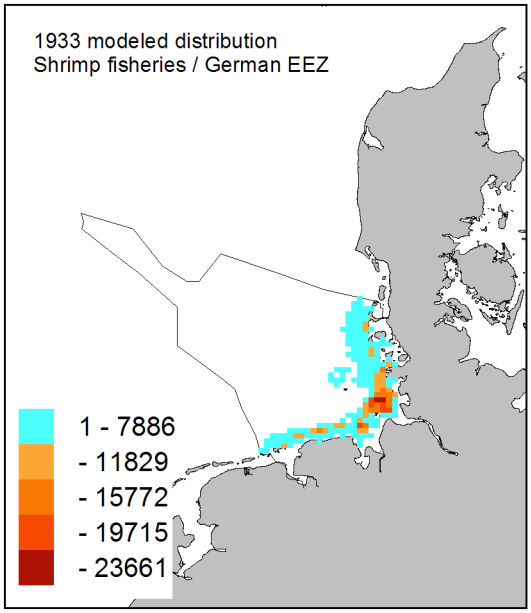

Fig. S3. Modeled historical shrimp fishing grounds in the German Bight in 1993 (after Fock 2014). Estimated hours fishing are indicated

Text S1. Stochastic surplus production model for thornback rays *Raja clavata* in the German Bight

SAS code

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*
Estimation of Fmsy for R. clavata
based on historical data

Method : Hilborn & Walters (1992) page 308  (Eq. 8.4.10)

-->     RATIO is conditionally bounded
-->     jackknife with 1 data row diminished
-->     effort is stochastically modelled : et_


Rescaling effort:
Steam trawler effort decreased in the southern North Sea (Fock 2014)
Effort separated in cutter and steam trawler effort
Proportion of catches see Fock et al. 2014

p               proportion for cutter (p_kutter) and steam trawler (p_st)
E               effort (trip days)
C               catch (plaice catch)
f/fstar         catch proportion clavata vs radiata/fullonica
q               catchability

C = q * E

C ~ E

C ~ p_kutter*E + (1-p_kutter)*E (=E_steamer)

C ~ (1 + p_kutter/(1-p_kutter))*E_steamer

Solve for E_Steamer and use Plaice catch C, then calculate total effort

ET = E_steamer/(1-p_kutter)

Factor f explains reduced share of R clavata in catches and increased proportions of R
fullonica/radiata Lundbeck 1937, p. 123).
The decline in f is in line with the decline of R clavata from survey catches (Fock et al. 2014),
with 90% clavata in period < 1923 to less afterwards

UT              total landings rays and skates
ET              total effort

*;
```

```
data raja;
input
year E_steamer UT     CPUE utplus1 cpueplus1 p_kutter fstar;

p_st=1-p_kutter;

ratio=cpueplus1/cpue-1;
if ratio<0 then ratio=0;
ET=E_steamer/(1-p_kutter);
cards;
1894 15610     218     478 183 540 .01 1
1899 13000     183     540 253 454 .01 1
1904 12133     253     454 265 462 .1 1
1909 11652     265     462 208 625 .23 1
1914 6712      208     625 418 615 .3 1
1920 11631     418     619 101 315 .32 1
1924 20600    101 315 12 233 .45 .28
1928 25000     12  133 1 108 .57 .15
1930 27500     1   108 0 10 .77 .03
;
run;

%macro raja(n);
%do no=1 %to &n;

data raja;
set raja;
ranuni=ranuni(0);
et_=et+ranuni*et*1;
f=0.9*fstar+0.1*fstar*rannor(0);
cpue=cpue*f;
cpueplus1=cpueplus1*f;
run;

proc sort data=raja;
by ranuni;
run;
data raja_;
set raja;
if _n_<9;
run;
* b3 control parameter, should be 0
  q  catchability, should be >0
  ;

proc nlin data=raja_ noprint outest=test1;
parms Fmsy=0 to .5 by .1 b1=0 to 1 by .1 q=0 to 1 by .1 b3=0 to 1 by 0.01;
model ratio=2*Fmsy-b1*cpue+b3-q*et_;
run;

data final;
set final test1;
where _TYPE_="FINAL";
run;
%end;
%Mend;
%raja(345);

data reduced;
set final;
if q>0 ;
run;
proc means data=reduced noprint;
var Fmsy;
where fmsy>0;
output out=finalres mean=fmsy uclm=upper lclm=lower;
run;
proc print;
run;
```

Table S1. Estimated age composition of thornback rays *Raja clavata* in survey catches in numbers per 30 min of trawling, for all quarters. Abundance, but no length, data were available in 1904 and 1905. nd: no data; blank cells: not applicable

Age (yr)														
	1902	1903	1904	1905	1906	1907	1908	1919	1920	1921	1923	1930	1931	1932
0						0.1						0.03	0.02	0.1
1	1.0	0.1	nd	nd	0.2	0.3		0.3				0.01	0.07	0.06
2	1.2	0.4	nd	nd	0.2	0.4		0.4	0.1	0.1	0.2	0.01	0.07	0.1
3	0.2	0.2	nd	nd	0.1	0.2		0.4	0.1	0.1	0.2			
4	0.5	0.1	nd	nd	0.1	0.1		0.4	0.2	0.1	0.2			
5	0.4	0.2	nd	nd	0.1	0.1		0.4	0.2	0.1	0.2			
6	0.4	0.1	nd	nd		0.1		0.3	0.1		0.1			
7	0.1		nd	nd				0.2						
8			nd	nd				0.1						
9			nd	nd										
10			nd	nd										

LITERATURE CITED

Fock HO (2014) Estimating historical trawling effort in the German Bight from 1924 to 1938. Fish Res 154:26–37

Fock HO, Kloppmann M, Probst WN (2014) An early footprint of fisheries: changes for a demersal fish assemblage in the German Bight from 1902–1932 to 1991–2009. J Sea Res 85:325–335

Hilborn R, Walters CJ (1992) Quantitative Fisheries Stock Assessment. Kluwer Academic Publishers, Boston, MA

Lundbeck J (1937) Biologisch-statistische Untersuchungen über die deutsche Hochseefischerei I. Ber Dtsch Wiss Komm Meeresforsch VIII:37–130