

Estimating efficiency of survey and commercial trawl gears from comparisons of catch-ratios

Nicola D. Walker, David L. Maxwell, Will J. F. Le Quesne, and Simon Jennings

Table S1. Species list for the North Sea fish community with species groups allocated: 1 – predominantly buried in sediment; 2 – on or near the seabed - anguilliform or fusiform; 3 – predominantly on the seabed - flat; 4 – predominantly close to the seabed, but not on it; 5 – midwater species with some seabed association; 6 – pelagic; 7 – predominantly on the seabed - lumpiform.

Species	Common	Code	Group
<i>Hyperoplus lanceolatus</i>	Great sandeel	GSE	1
<i>Hyperoplus immaculatus</i>	Immaculate sandeel	ISE	1
<i>Gymnammodytes semisquamatus</i>	Smooth sandeel	SMS	1
<i>Solea solea</i>	Sole	SOL	1
<i>Solea lascaris</i>	Sand sole	SOS	1
<i>Buglossidium luteum</i>	Solenette	SOT	1
<i>Ammodytes tobianus</i>	Sandeel	TSE	1
<i>Trachinus draco</i>	Greater weever	WEG	1
<i>Echiichthys vipera</i>	Lesser weever	WEL	1
<i>Molva dypterygia</i>	Blue ling	BLI	2
<i>Pholis gunnellus</i>	Butter fish	BTF	2
<i>Conger conger</i>	Conger eel	COE	2
<i>Anguilla anguilla</i>	European eel	ELE	2
<i>Enchelyopus cimbrius</i>	Fourbeard rockling	FRR	2
<i>Ciliata mustela</i>	Fivebeard rockling	FVR	2
<i>Myxine glutinosa</i>	Hagfish	HGF	2
<i>Molva molva</i>	Common ling	LIN	2
<i>Lumpenus lampretaeformis</i>	Snake blenny	SBY	2
<i>Pomatoschistus minutus</i>	Sand goby	SDG	2
<i>Leptoclinus maculatus</i>	Spotted snake blenny	SNB	2
<i>Gaidropsarus vulgaris</i>	Threebeard rockling	TBR	2
<i>Lycodes vahlii</i>	Vahl's eelpout	VLP	2
<i>Scophthalmus rhombus</i>	Brill	BLL	3
<i>Raja brachyura</i>	Blonde ray	BLR	3
<i>Leucoraja naevus</i>	Cuckoo ray	CUR	3
<i>Limanda limanda</i>	Dab	DAB	3
<i>Phrynorhombus regius</i>	Ekstroms topknot	EKT	3
<i>Platichthys flesus</i>	Flounder	FLE	3

<i>Hippoglossus hippoglossus</i>	Halibut	HAL	3
<i>Arnoglossus imperialis</i>	Imperial scaldfish	ISF	3
<i>Lepidorhombus boscii</i>	Four spot megrim	LBI	3
<i>Microstomus kitt</i>	Lemon sole	LEM	3
<i>Dipturus oxyrinchus</i>	Long-nose skate	LNS	3
<i>Lepidorhombus whiffiagonis</i>	Megrim	MEG	3
<i>Phrynorhombus norvegicus</i>	Norwegian topknot	NKT	3
<i>Hippoglossoides platessoides</i>	Long rough dab	PLA	3
<i>Pleuronectes platessa</i>	Plaice	PLE	3
<i>Raja microocellata</i>	Small-eyed ray	PTR	3
<i>Leucoraja circularis</i>	Sandy ray	SAR	3
<i>Arnoglossus laterna</i>	Scald fish	SDF	3
<i>Raja montagui</i>	Spotted ray	SDR	3
<i>Leucoraja fullonica</i>	Shagreen ray	SHR	3
<i>Raja batis</i>	Common skate	SKT	3
<i>Amblyraja radiata</i>	Starry ray	SYR	3
<i>Microchirus variegatus</i>	Thickback sole	TBS	3
<i>Raja clavata</i>	Thornback ray	THR	3
<i>Zeugopterus punctatus</i>	Topknot	TKT	3
<i>Scophthalmus maximus</i>	Turbot	TUR	3
<i>Raja undulata</i>	Undulate ray	UNR	3
<i>Glyptocephalus cynoglossus</i>	Witch	WIT	3
<i>Trisopterus luscus</i>	Bib	BIB	4
<i>Spondyliosoma cantharus</i>	Black seabream	BKS	4
<i>Labrus bergylta</i>	Ballan wrasse	BNW	4
<i>Gadus morhua</i>	Cod	COD	4
<i>Ctenolabrus rupestris</i>	Goldsinny	GDY	4
<i>Syngnathus acus</i>	Great pipefish	GPF	4
<i>Melanogrammus aeglefinus</i>	Haddock	HAD	4
<i>Merluccius merluccius</i>	Hake	HKE	4
<i>Zeus faber</i>	John dory	JOD	4
<i>Mullus barbatus</i>	Red mullet	MBB	4
<i>Mullus surmuletus</i>	Red mullet	MUR	4
<i>Syngnathus rostellatus</i>	Nilsson's pipefish	NPF	4
<i>Trisopterus minutus</i>	Poor cod	POD	4
<i>Pollachius virens</i>	Saithe	POK	4
<i>Pollachius pollachius</i>	Pollack	POL	4
<i>Chimaera monstrosa</i>	Rabbit fish	RBF	4
<i>Sebastes marinus</i>	Norway haddock	REG	4
<i>Sebastes viviparus</i>	Redfish	REV	4
<i>Mustelus asterias</i>	Starry smooth hound	SDS	4
<i>Mustelus mustelus</i>	Smooth hound	SMH	4
<i>Balistes carolinensis</i>	Trigger fish	TRF	4
<i>Merlangius merlangus</i>	Whiting	WHG	4

<i>Squalus acanthias</i>	Spurdog	DGS	5
<i>Dicentrarchus labrax</i>	Seabass	ESB	5
<i>Galeorhinus galeus</i>	Tope shark	GAG	5
<i>Argentina silus</i>	Great silver smelt	GSS	5
<i>Argentina sphyraena</i>	Lesser silver smelt	LSS	5
<i>Liza aurata</i>	Golden mullet	MGN	5
<i>Trisopterus esmarki</i>	Norway pout	NOP	5
<i>Hexanchus griseus</i>	Six-gilled shark	SGS	5
<i>Petromyzon marinus</i>	Sea lamprey	SLY	5
<i>Osmerus eperlanus</i>	Smelt	SME	5
<i>Gadiculus argenteus</i>	Silvery pout	SYP	5
<i>Etmopterus spinax</i>	Velvet belly	VBY	5
<i>Micromesistius poutassou</i>	Blue whiting	WHB	5
<i>Alosa alosa</i>	Allis shad	AAS	6
<i>Engraulis encrasiculus</i>	Anchovy	ANE	6
<i>Crystallogobius linearis</i>	Crystal goby	CLG	6
<i>Belone belone</i>	Garfish	GAR	6
<i>Clupea harengus</i>	Herring	HER	6
<i>Trachurus trachurus</i>	Horse-mackerel	HOM	6
<i>Scomber scombrus</i>	Mackerel	MAC	6
<i>Liza ramada</i>	Thin lipped mullet	MTN	6
<i>Maurolicus muelleri</i>	Pearlside	PLS	6
<i>Brama brama</i>	Rays bream	POA	6
<i>Lamna nasus</i>	Porbeagle	POR	6
<i>Entelurus aequoreus</i>	Snake pipefish	SKP	6
<i>Atherina presbyter</i>	Sand smelt	SMT	6
<i>Sprattus sprattus</i>	Sprat	SPR	6
<i>Alosa fallax</i>	Twaite shad	TAS	6
<i>Aphia minuta</i>	Transparent goby	TPG	6
<i>Salmo trutta</i>	Sea trout	TRS	6
<i>Gobius niger</i>	Black goby	BLG	7
<i>Myoxocephalus scorpius</i>	Bullrout	BRT	7
<i>Anarhichas lupus</i>	Catfish	CAA	7
<i>Callionymus lyra</i>	Common dragonet	CDT	7
<i>Galeus melastomus</i>	Blackmouthed dogfish	DBM	7
<i>Scyliorhinus stellaris</i>	Greater spotted dogfish	DGN	7
<i>Zoarces viviparus</i>	Eelpout	ELP	7
<i>Phycis blennoides</i>	Greater forkbeard	GFB	7
<i>Eutrigla gurnardus</i>	Grey gurnard	GUG	7
<i>Aspitrigla cuculus</i>	Red gurnard	GUR	7
<i>Raniceps raninus</i>	Tadpole fish	LFB	7
<i>Scyliorhinus canicula</i>	Lesser spotted dogfish	LSD	7
<i>Cyclopterus lumpus</i>	Lumpsucker	LUM	7
<i>Lophius piscatorius</i>	Anglerfish	MON	7

<i>Myoxocephalus quadricornis</i>	Fourhorn sculpin	MQS	7
<i>Liparis montagui</i>	Montagu's seasnail	MSS	7
<i>Agonus cataphractus</i>	Pogge	POG	7
<i>Helicolenus dactylopterus</i>	Blue-mouth redfish	RBM	7
<i>Callionymus reticulatus</i>	Reticulate dragonet	RDT	7
<i>Lepadogaster lepadogaster</i>	Shore clingfish	SCF	7
<i>Callionymus maculatus</i>	Spotted dragonet	SDT	7
<i>Triglops murrayi</i>	Sculpin	SPN	7
<i>Taurulus bubalis</i>	Sea scorpion	SSN	7
<i>Trigla lucerna</i>	Tub gurnard	TUB	7
<i>Brosme brosme</i>	Tusk	USK	7
<i>Lophius budegassa</i>	Black-bellied angler	WAF	7

Table S2. Raising factors calculated by year and subarea for the IBTS Q1 survey.

Year	IVa1	IVa2	IVb1	IVb2	IVc
2002	1.502	1.609	1.043	1.045	1.121
2003	1.451	1.609	1.017	1.028	1.121
2004	1.451	1.609	1.017	1.028	1.121
2005	1.374	1.609	1.027	1.028	1.121
2006	1.451	1.609	1.027	1.028	1.121
2007	1.374	1.609	1.017	1.028	1.121
2008	1.374	1.671	1.027	1.028	1.121
2009	1.374	1.609	1.027	1.028	1.137
2010	1.293	1.609	1.027	1.028	1.104
2011	1.293	1.609	1.027	1.028	1.104
2012	1.293	1.609	1.027	1.028	1.121
2013	1.220	1.671	1.027	1.028	1.104
2014	1.220	1.739	1.027	1.052	1.121
2015	1.293	1.609	1.027	1.028	1.121

Table S3. Raising factors calculated by year and subarea for the IBTS Q3 survey.

Year	IVa1	IVa2	IVb1	IVb2	IVc
2002	1.322	1.611	1.043	1.101	1.340
2003	1.407	1.496	1.043	1.129	1.422
2004	1.322	1.554	1.043	1.158	1.340
2005	1.362	1.554	1.043	1.101	1.340
2006	1.362	1.609	1.043	1.101	1.340
2007	1.283	1.554	1.043	1.158	1.340
2008	1.322	1.554	1.043	1.101	1.340
2009	1.293	1.671	1.043	1.082	1.340
2010	1.220	1.609	1.043	1.129	1.422
2011	1.220	1.547	1.043	1.101	1.340
2012	1.157	1.554	1.043	1.101	1.340
2013	1.220	1.491	1.043	1.131	1.340
2014	1.220	1.491	1.043	1.101	1.340
2015	1.157	1.444	1.027	1.101	1.340

Table S4. Raising factors calculated by year and subarea for the BTS survey.

Year	IVa1	IVa2	IVb1	IVb2	IVc
2002	7.206	3.744	1.217	1.071	1.186
2003	3.580	6.697	1.353	1.071	1.186
2004	5.324	8.018	1.398	1.156	1.121
2005	4.710	10.023	1.398	1.126	1.293
2006	4.710	13.363	1.301	1.220	1.215
2007	4.710	10.023	1.347	1.097	1.177
2008	5.324	8.040	1.301	1.097	1.689
2009	6.124	6.712	1.299	1.097	1.215
2010	6.124	40.090	1.347	1.190	1.215
2011	5.324	6.712	1.214	1.093	1.404
2012	5.324	5.761	1.298	1.097	1.271
2013	6.124	5.761	1.256	1.045	1.423
2014	6.124	6.728	1.256	1.140	1.215
2015	5.324	5.761	1.256	1.097	1.121

Table S5. Assessment areas and the proportion they contribute to each assessment.

Species	ICES area	Proportion
Sole	IV	1.000
Plaice	IIIaW	0.048
	IV	0.952
Cod	IIIaW	0.045
	IV	0.901
	VIId	0.054
Norway pout	IIIa	0.315
	IV	0.685
Herring	IIIa	0.303
	IV	0.658
	VIId	0.039

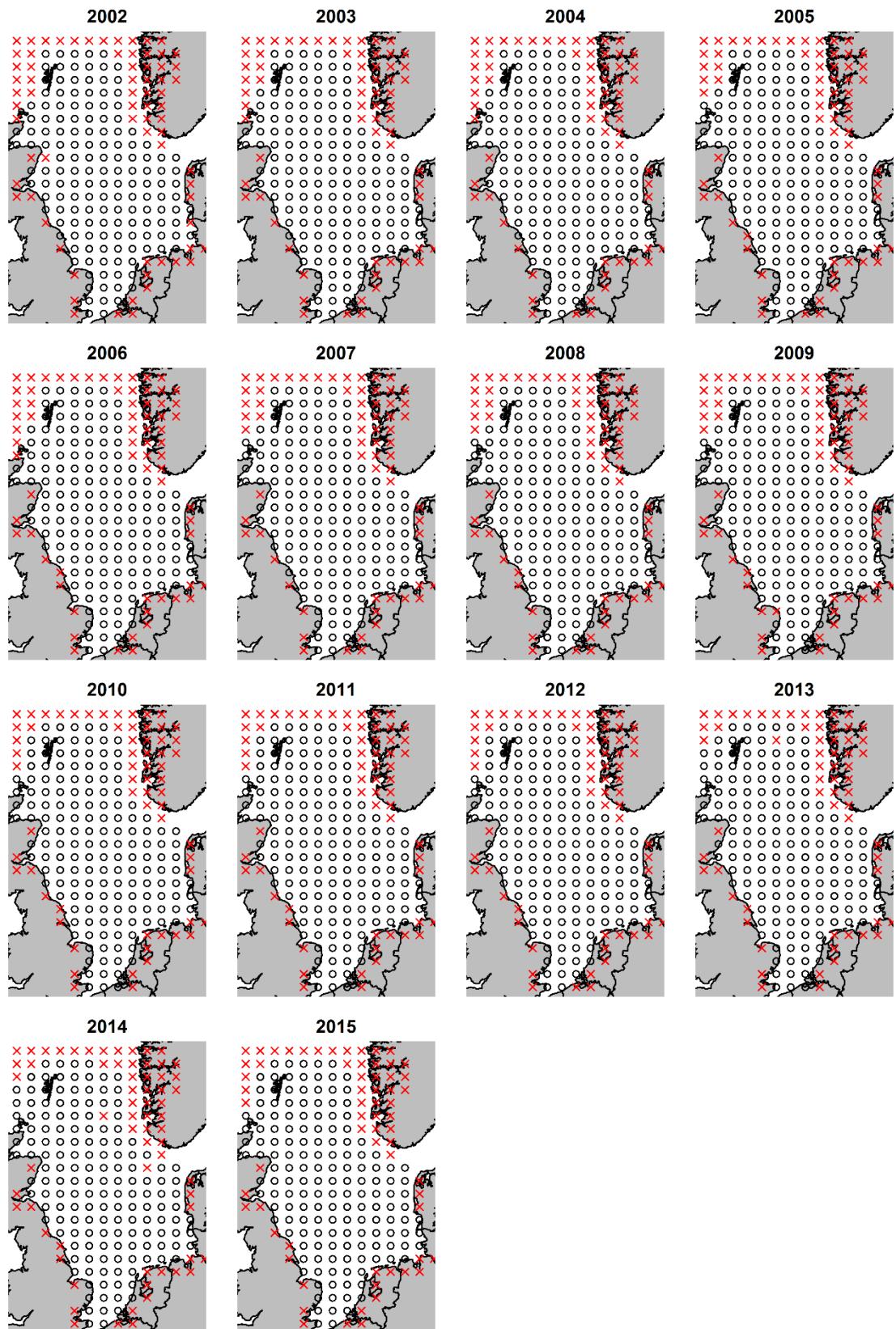


Figure S1. Rectangles sampled in the IBTS Q1 survey. Circles indicate rectangles where at least one haul was recorded in a given year.

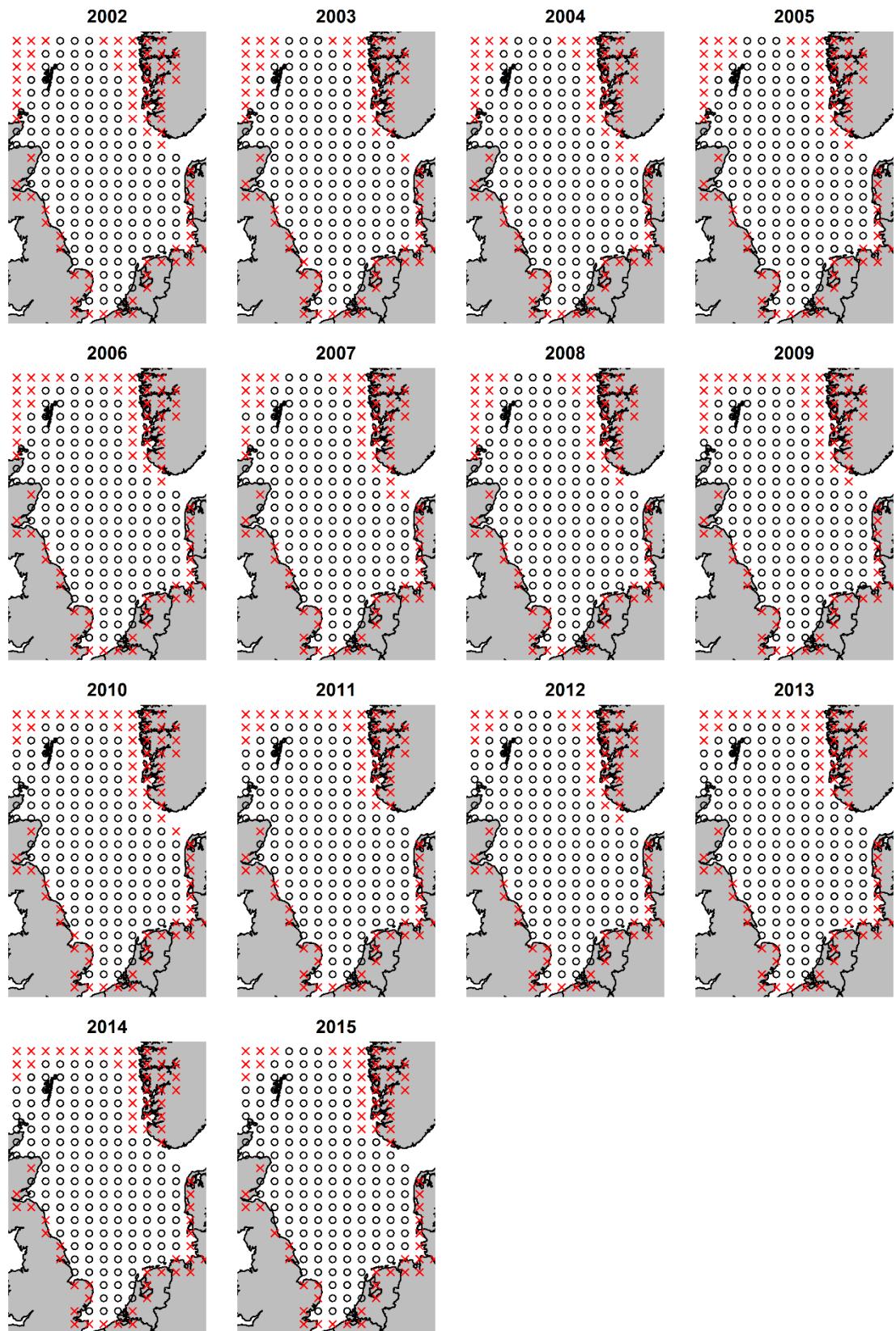


Figure S2. Rectangles sampled in the IBTS Q3 survey. Circles indicate rectangles where at least one haul was recorded in a given year.

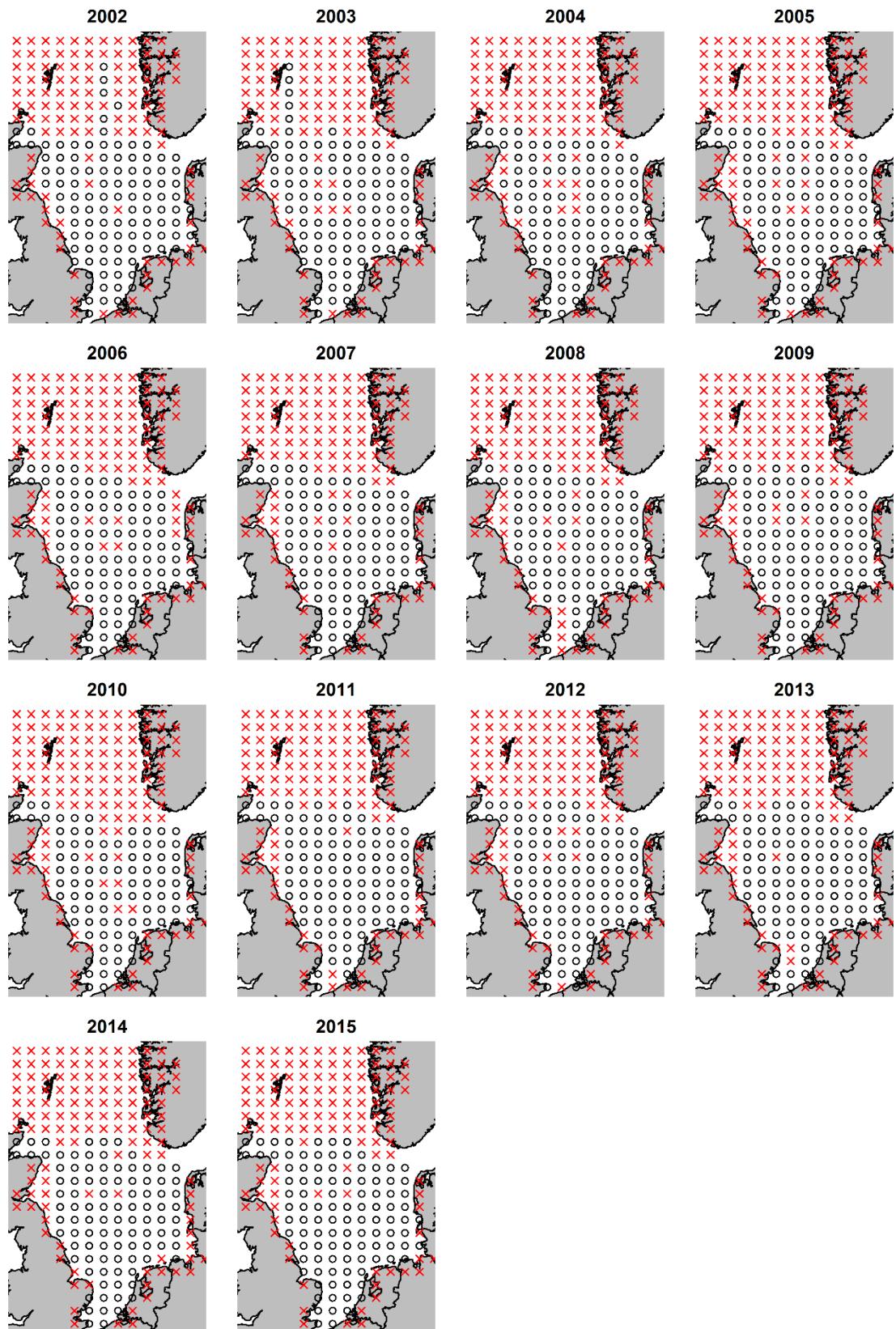


Figure S3. Rectangles sampled in the BTS Q3 survey. Circles indicate rectangles where at least one haul was recorded in a given year.

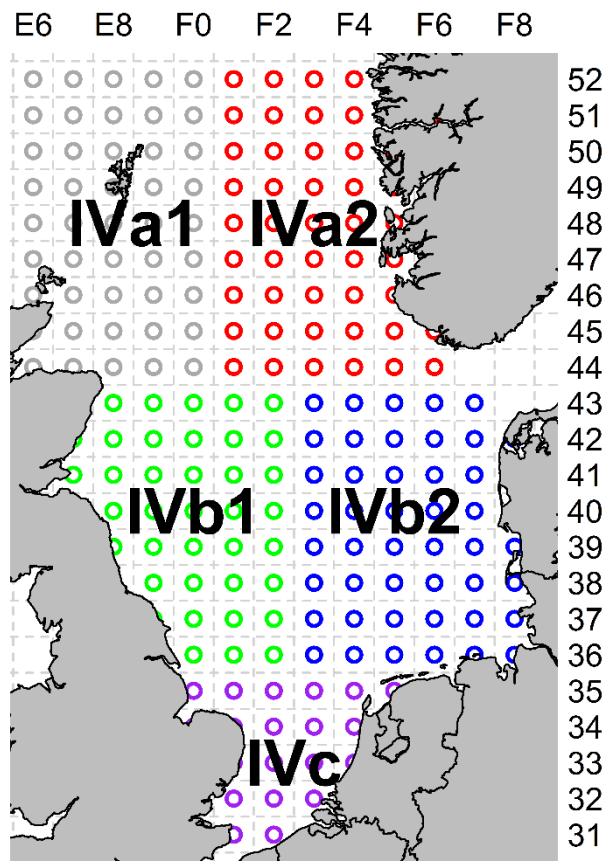


Figure S4. The five subareas used to calculate raising factors (Fraser *et al.*, 2007).

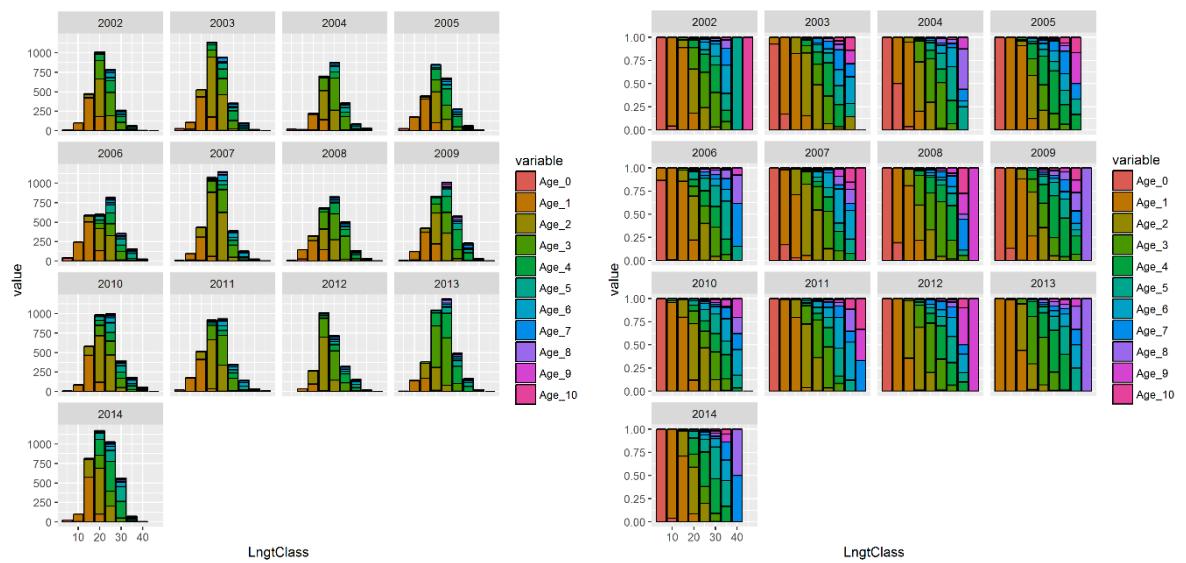
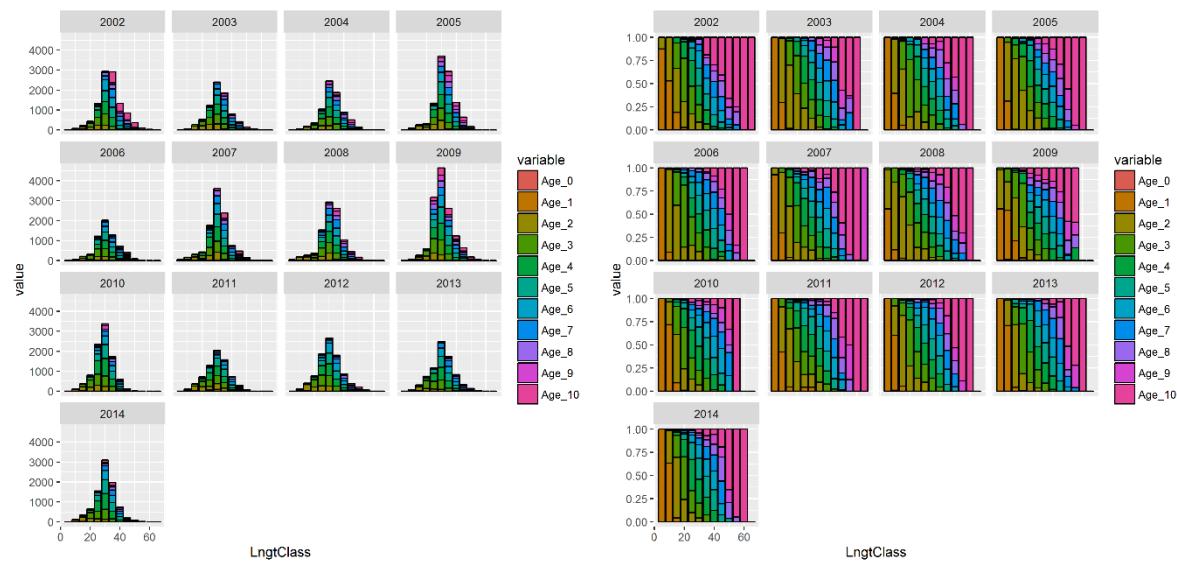


Figure S5. Length-at-age distributions for sole (species-group 1) from BTS sampling and the resulting age-length keys.

Quarter 1



Quarter 3

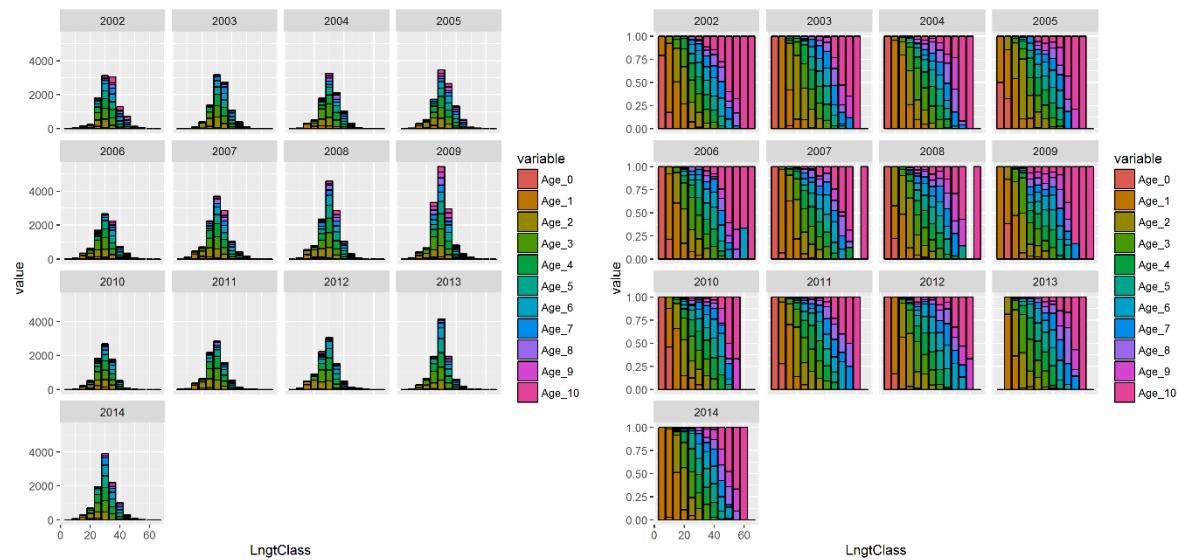
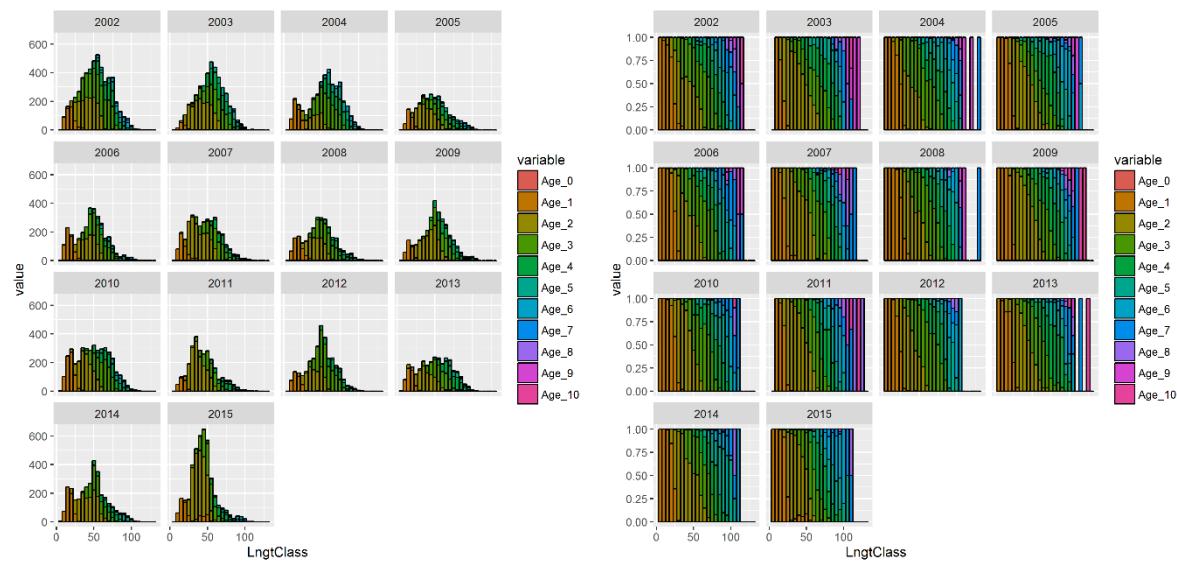


Figure S6. Length-at-age distributions for plaice (species-group 3) from IBTS and observer sampling and the resulting age-length keys

Quarter 1



Quarter 3

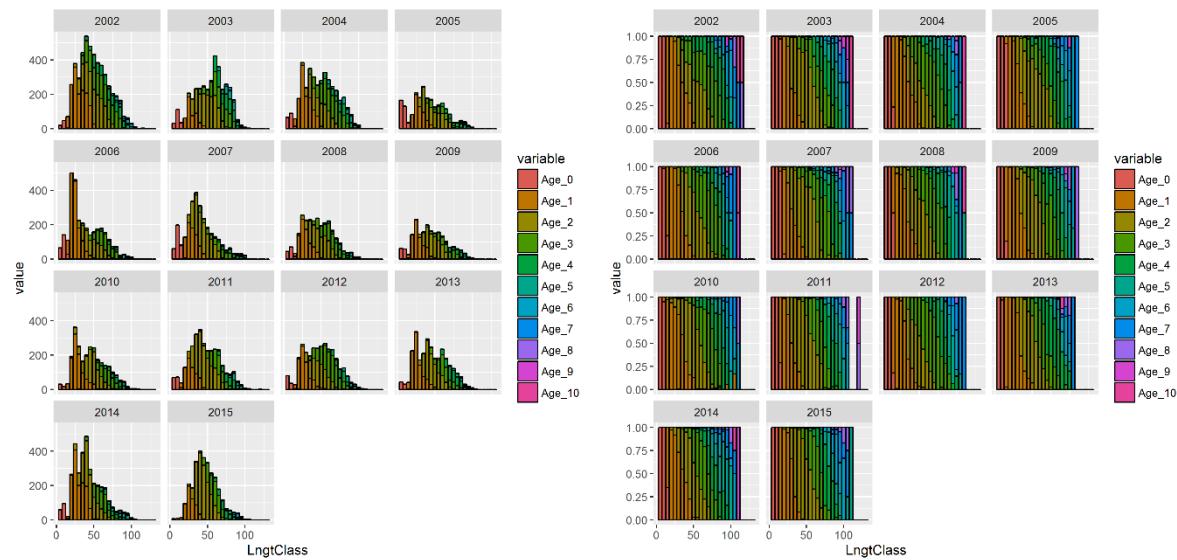
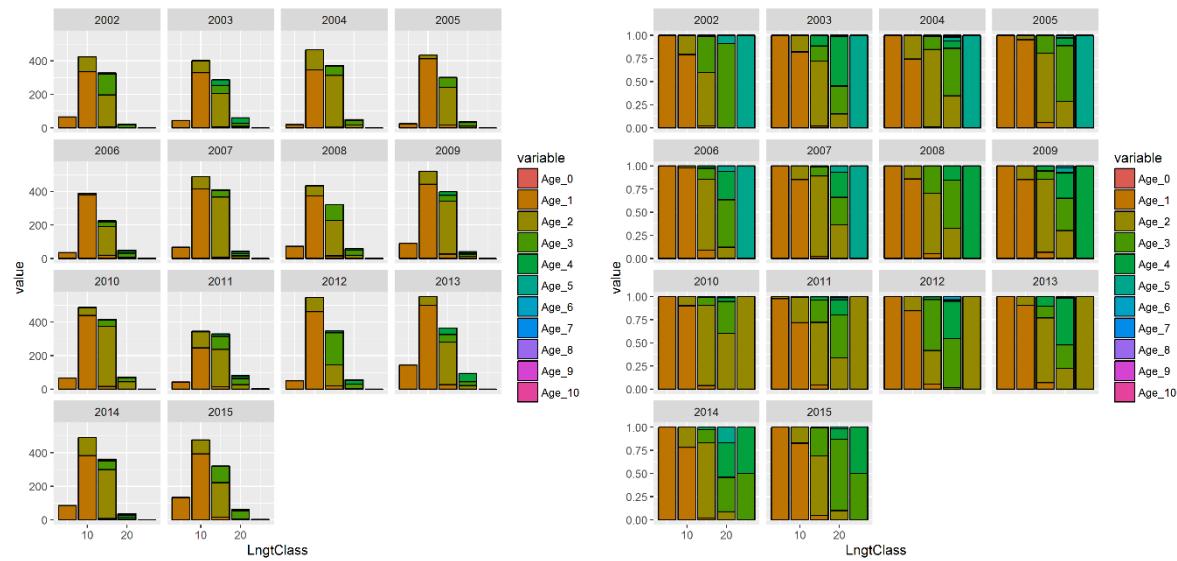


Figure S7. Length-at-age distributions for cod (species-group 4) from IBTS and observer sampling and the resulting age-length keys.

Quarter 1



Quarter 3

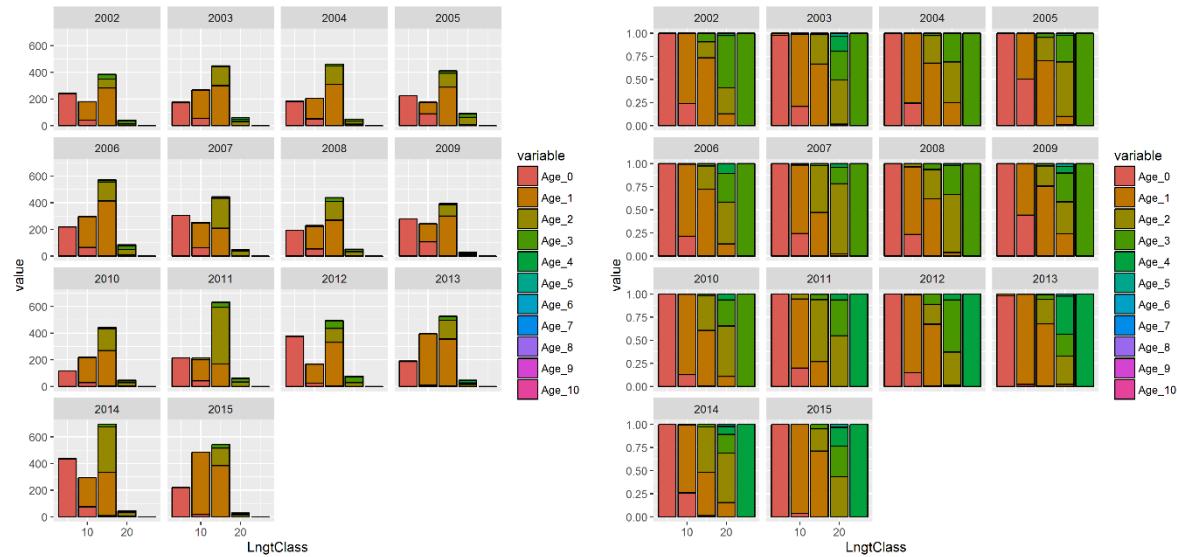
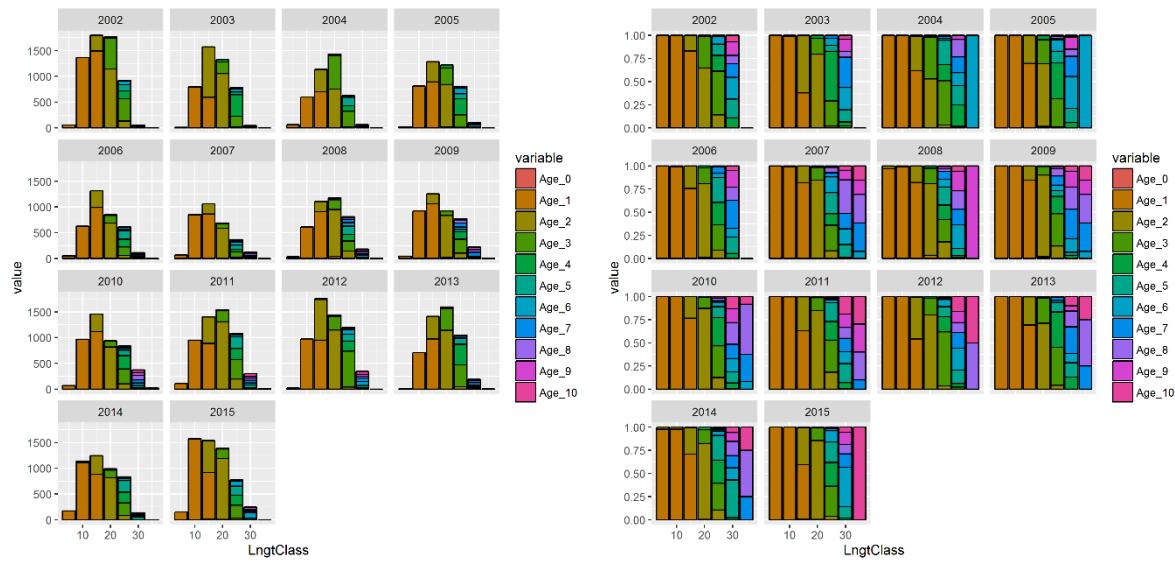


Figure S8. Length-at-age distributions for Norway pout (species-group 5) from IBTS sampling and the resulting age-length keys.

Quarter 1



Quarter 3

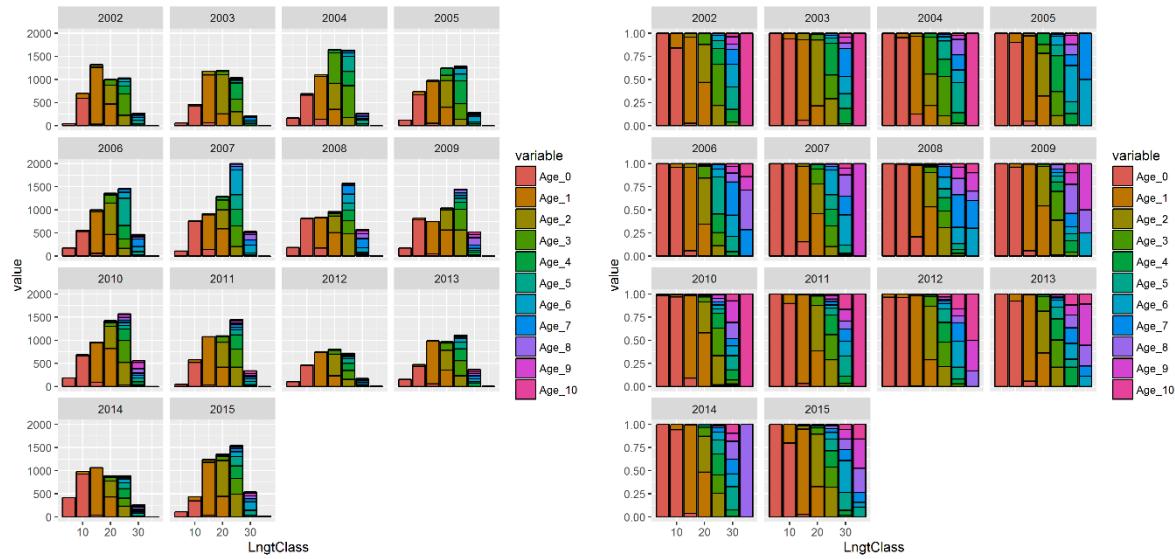


Figure S9. Length-at-age distributions for herring (species-group 6) from IBTS sampling and the resulting age-length keys

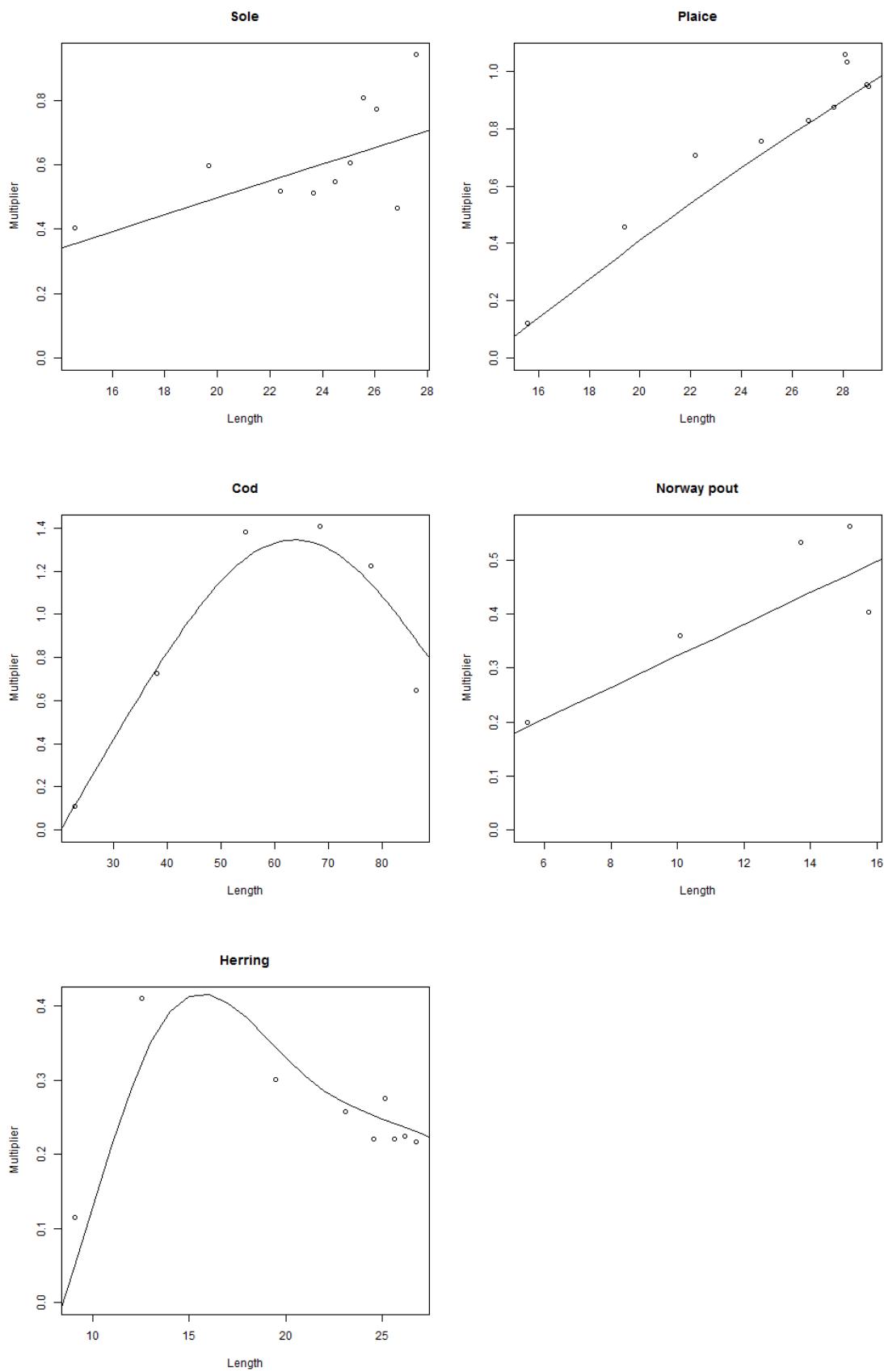


Figure S10. GAM curves fitted to efficiency multipliers-at-age/length to estimate multipliers for each length class.

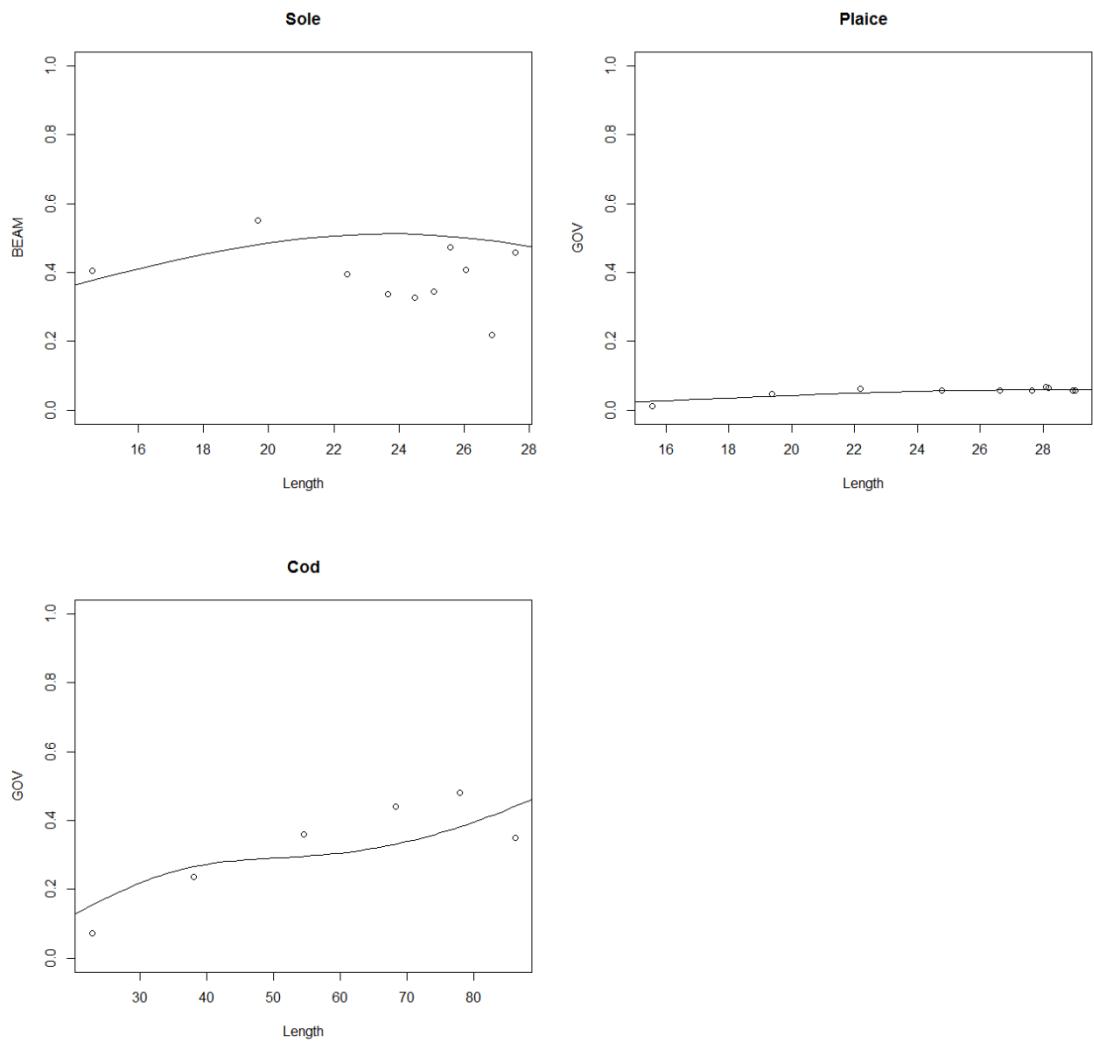


Figure S11. Direct estimates of survey gear efficiency-at-age/length for assessed species (dots) compared to the final efficiency curves obtained for those gears.

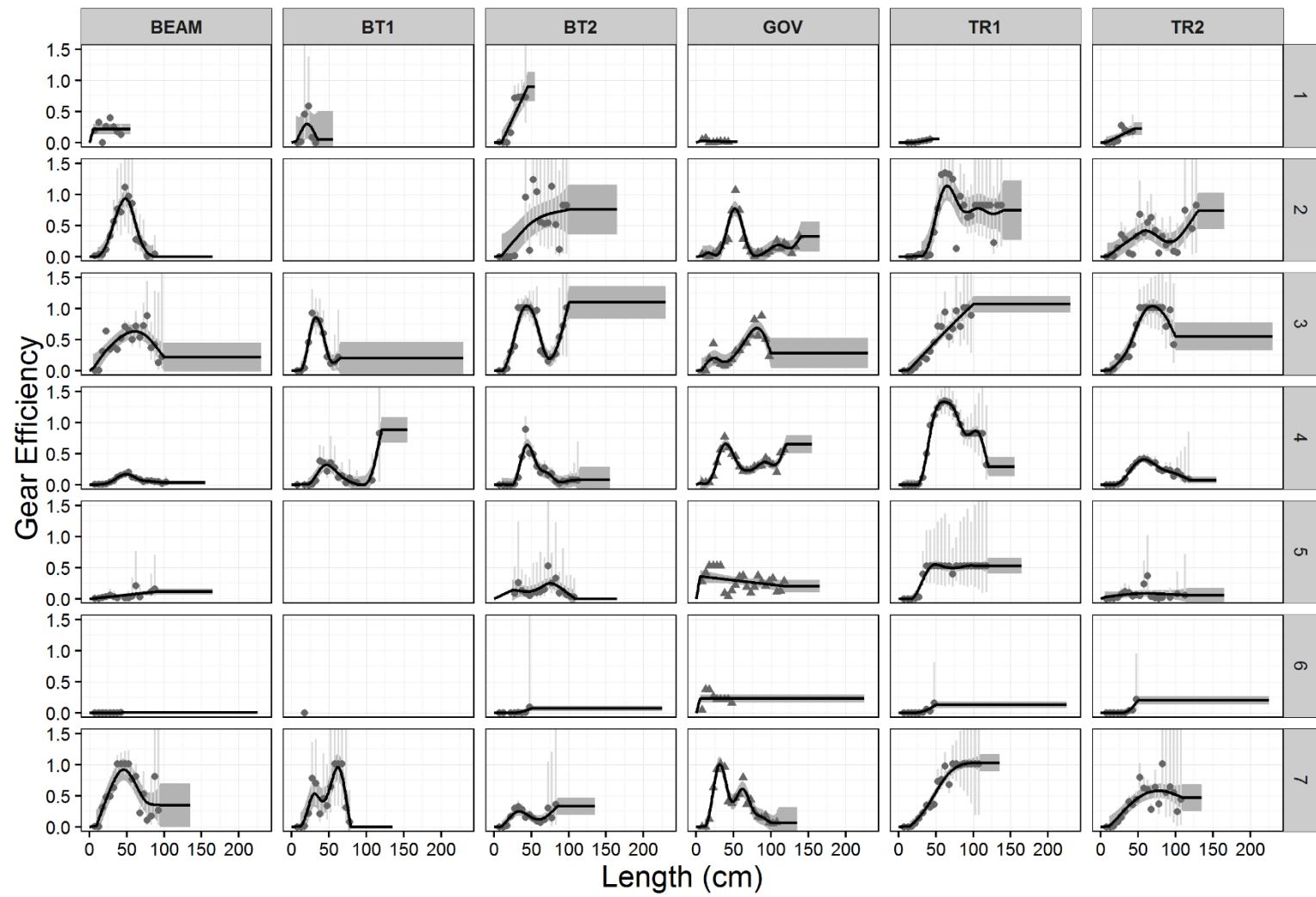


Figure S12. Relationships between gear efficiency and length for the seven species groups. Vertical bars show 95% confidence intervals about estimates of absolute efficiency and shaded regions 95% confidence intervals about the fitted curves. Triangles indicate the reference gear used to derive catch ratios.

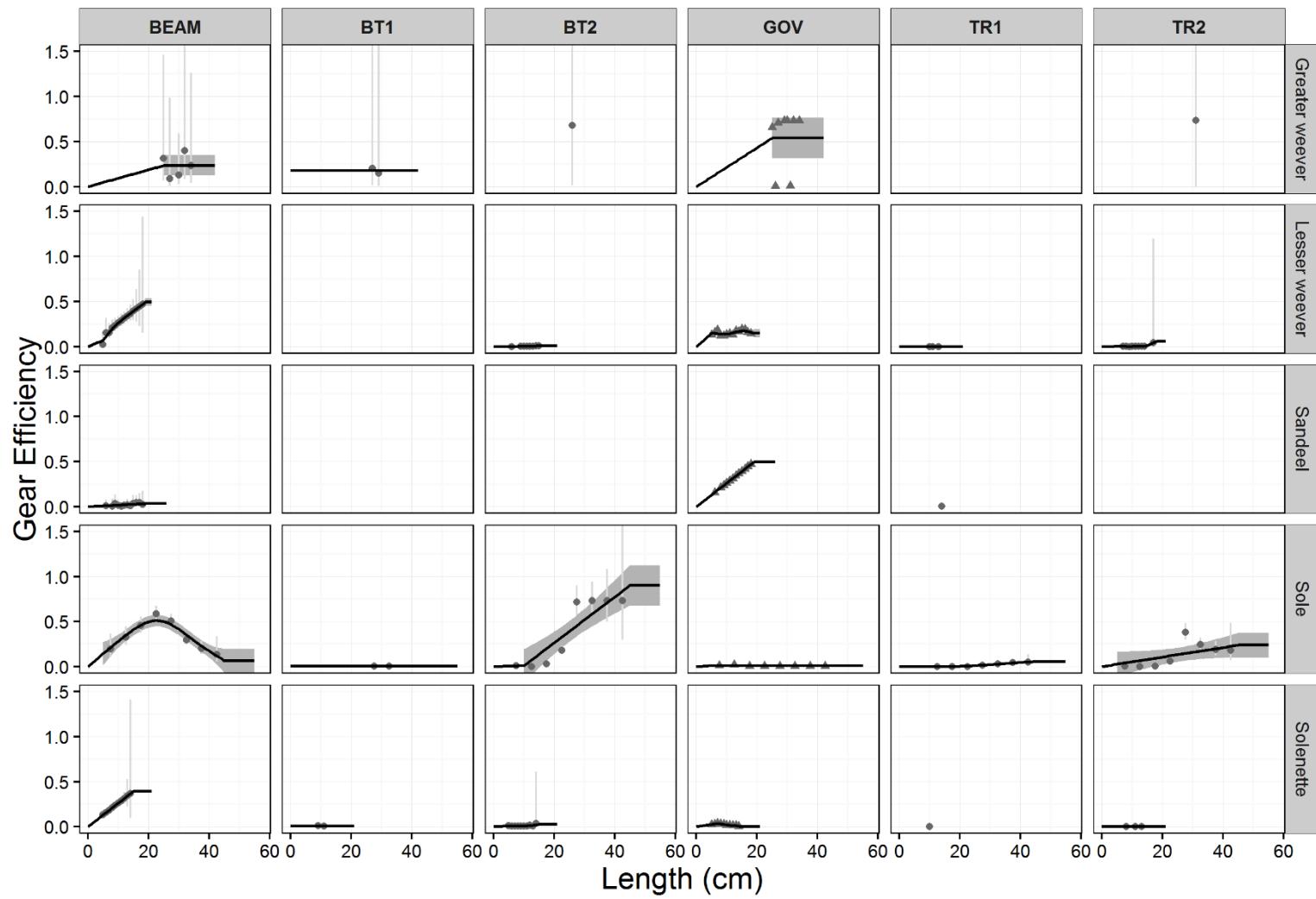


Figure S13. Relationships between gear efficiency and length for species in group 1. Vertical bars show 95% confidence intervals about estimates of absolute efficiency and shaded regions 95% confidence intervals about the fitted curves. Triangles indicate the reference gear used to derive catch ratios.

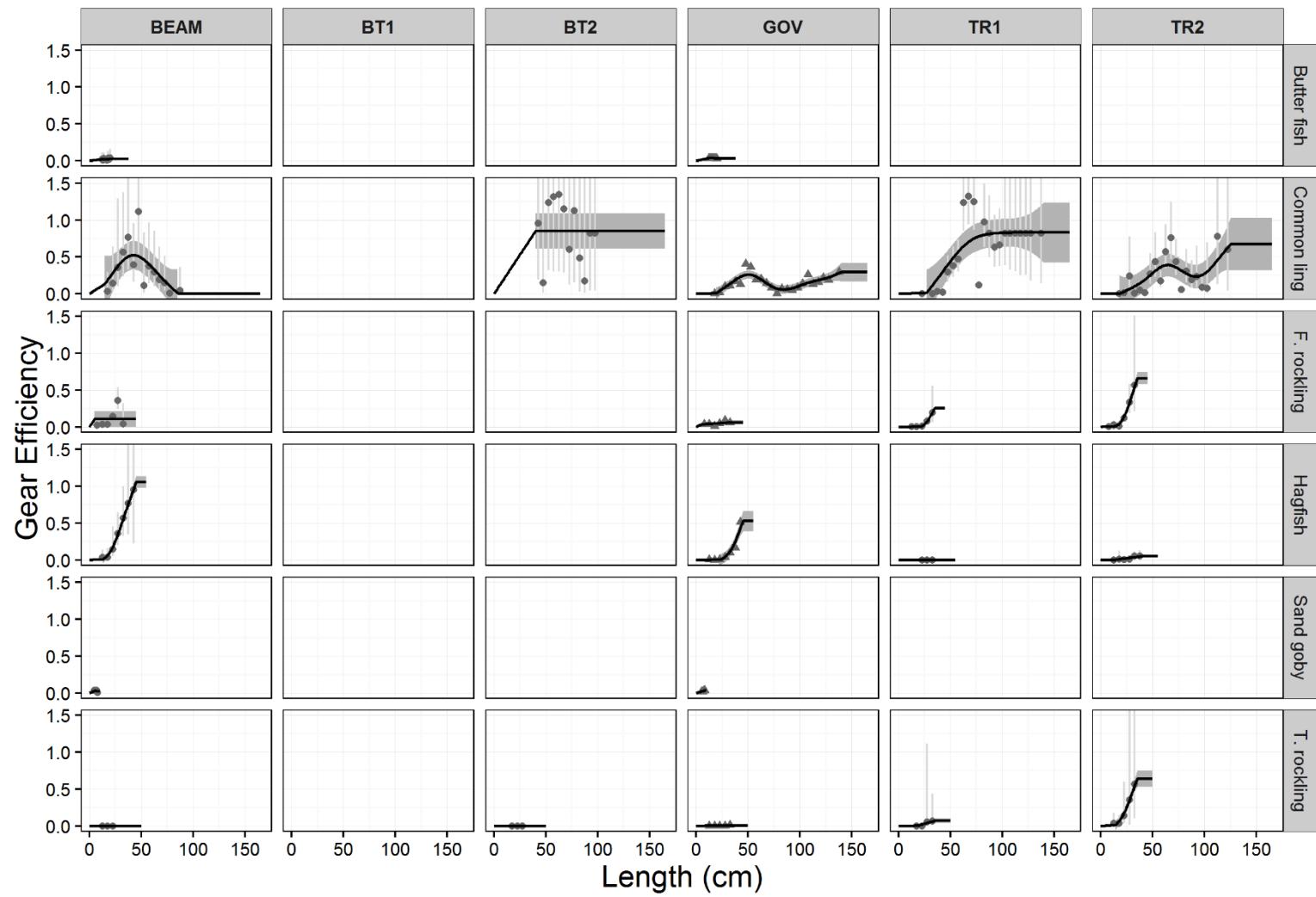


Figure S14. Relationships between gear efficiency and length for species in group 2. Vertical bars show 95% confidence intervals about estimates of absolute efficiency and shaded regions 95% confidence intervals about the fitted curves. Triangles indicate the reference gear used to derive catch ratios.

F. rockling = Fourbeard rockling; T. rockling = Threebeard rockling

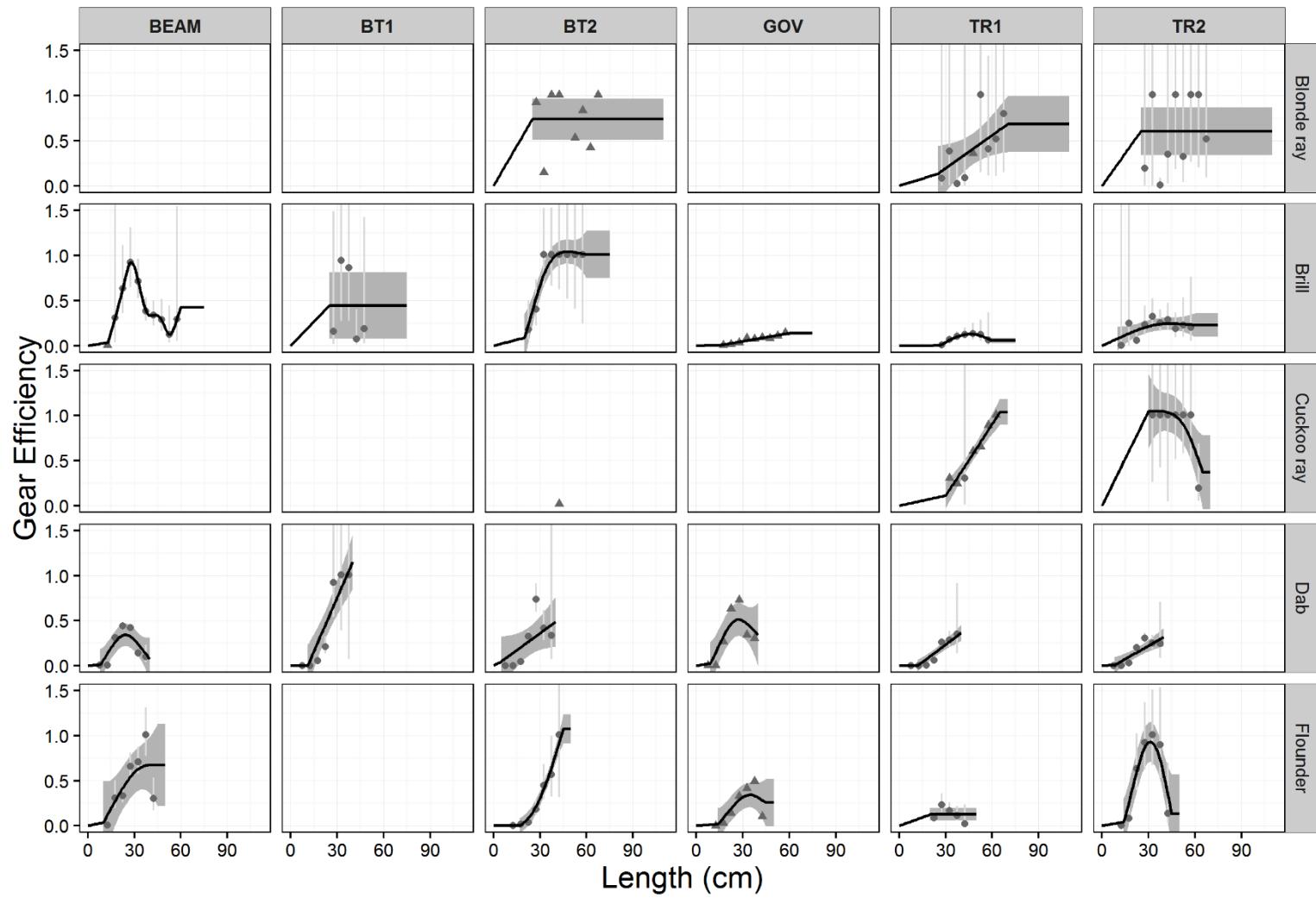


Figure S15. Relationships between gear efficiency and length for species in group 3. Vertical bars show 95% confidence intervals about estimates of absolute efficiency and shaded regions 95% confidence intervals about the fitted curves. Triangles indicate the reference gear used to derive catch ratios.

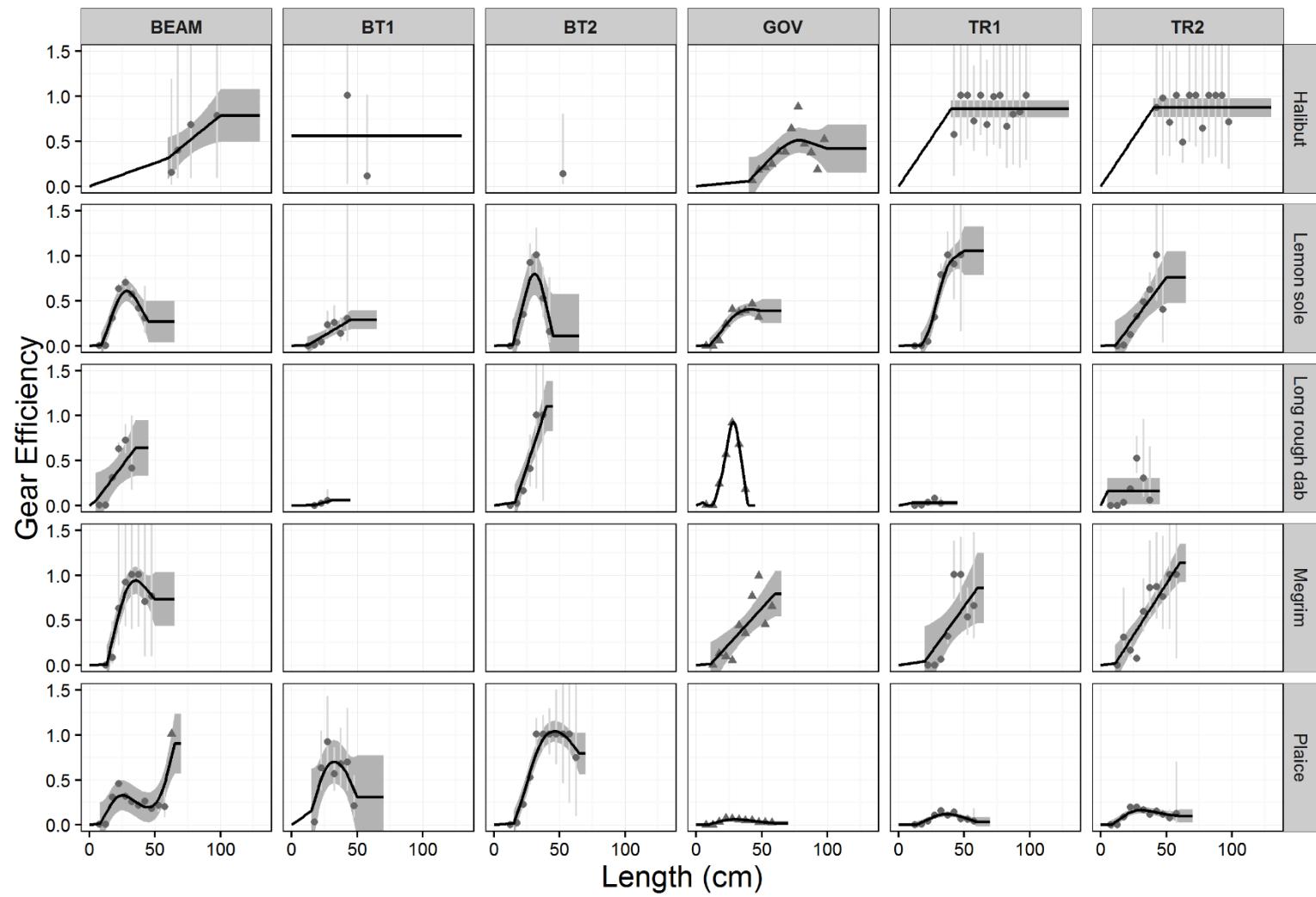


Figure S15 cont. Relationships between gear efficiency and length for species in group 3. Vertical bars show 95% confidence intervals about estimates of absolute efficiency and shaded regions 95% confidence intervals about the fitted curves. Triangles indicate the reference gear used to derive catch ratios.

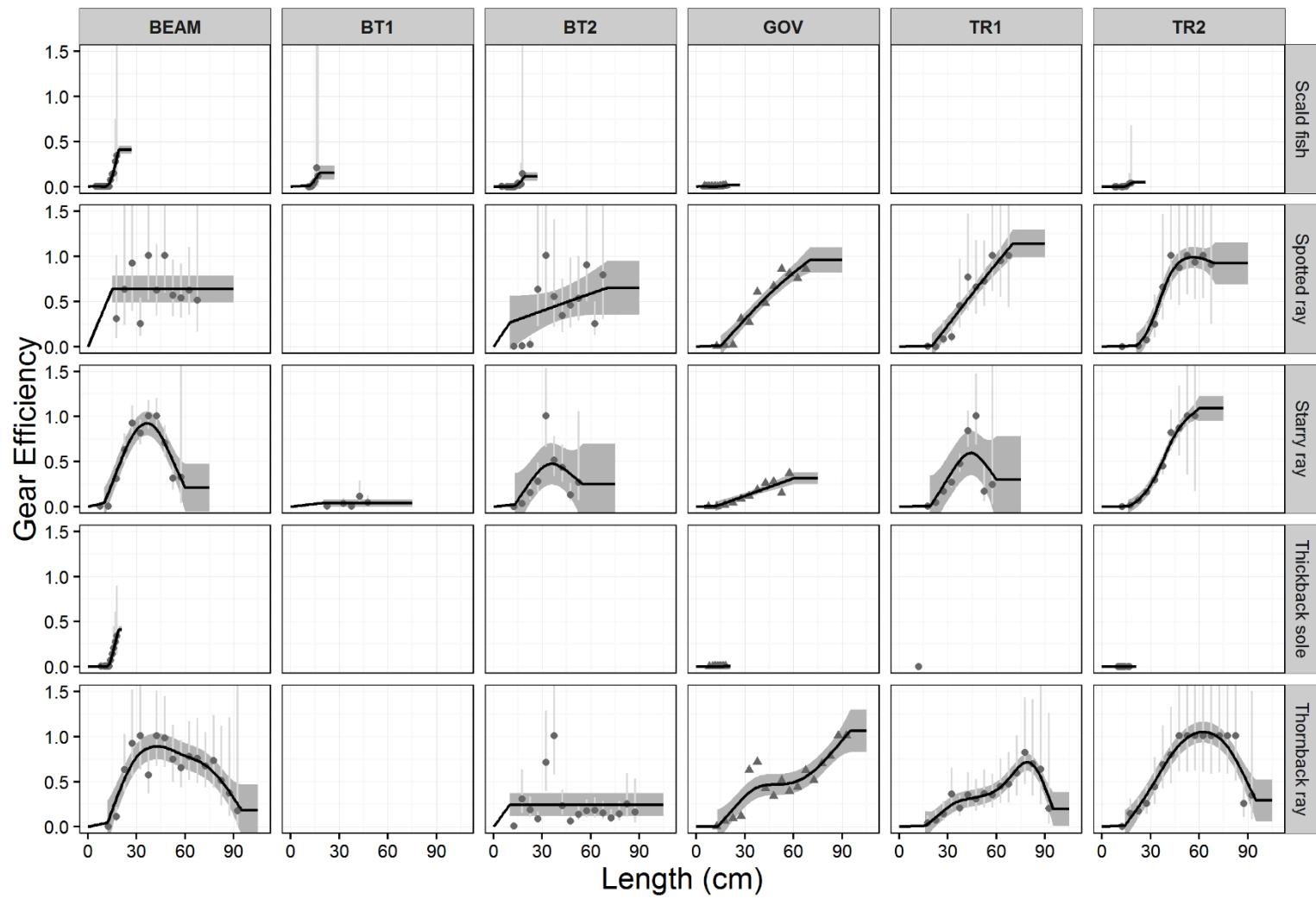


Figure S15 cont. Relationships between gear efficiency and length for species in group 3. Vertical bars show 95% confidence intervals about estimates of absolute efficiency and shaded regions 95% confidence intervals about the fitted curves. Triangles indicate the reference gear used to derive catch ratios.

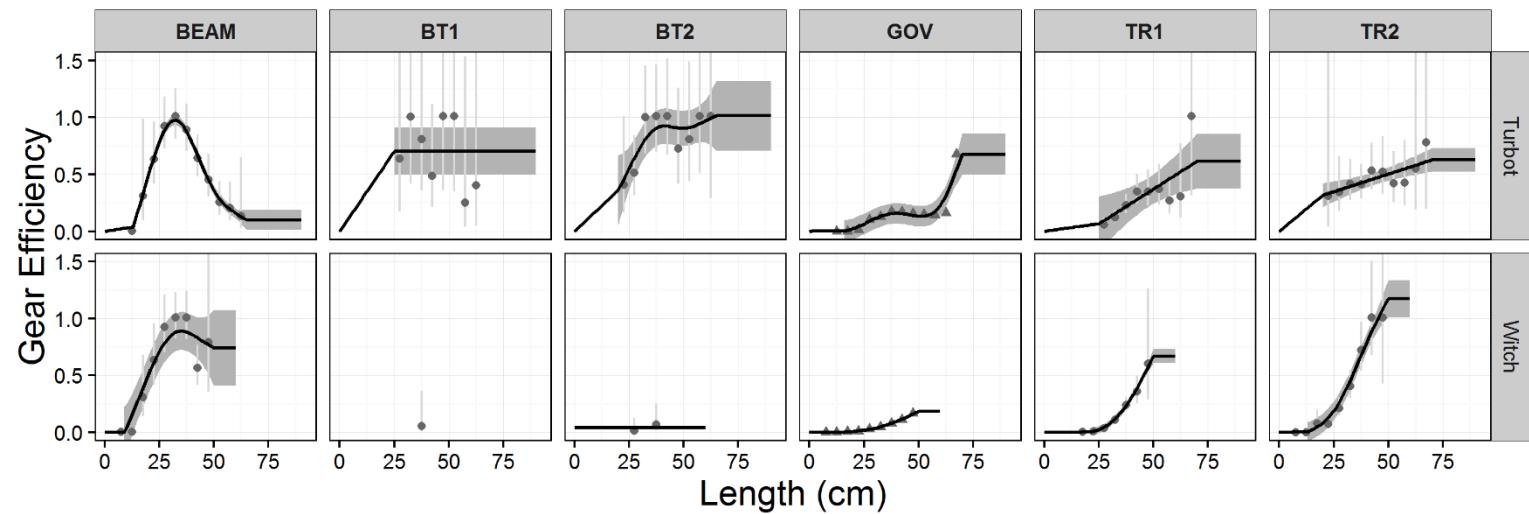


Figure S15 cont. Relationships between gear efficiency and length for species in group 3. Vertical bars show 95% confidence intervals about estimates of absolute efficiency and shaded regions 95% confidence intervals about the fitted curves. Triangles indicate the reference gear used to derive catch ratios.

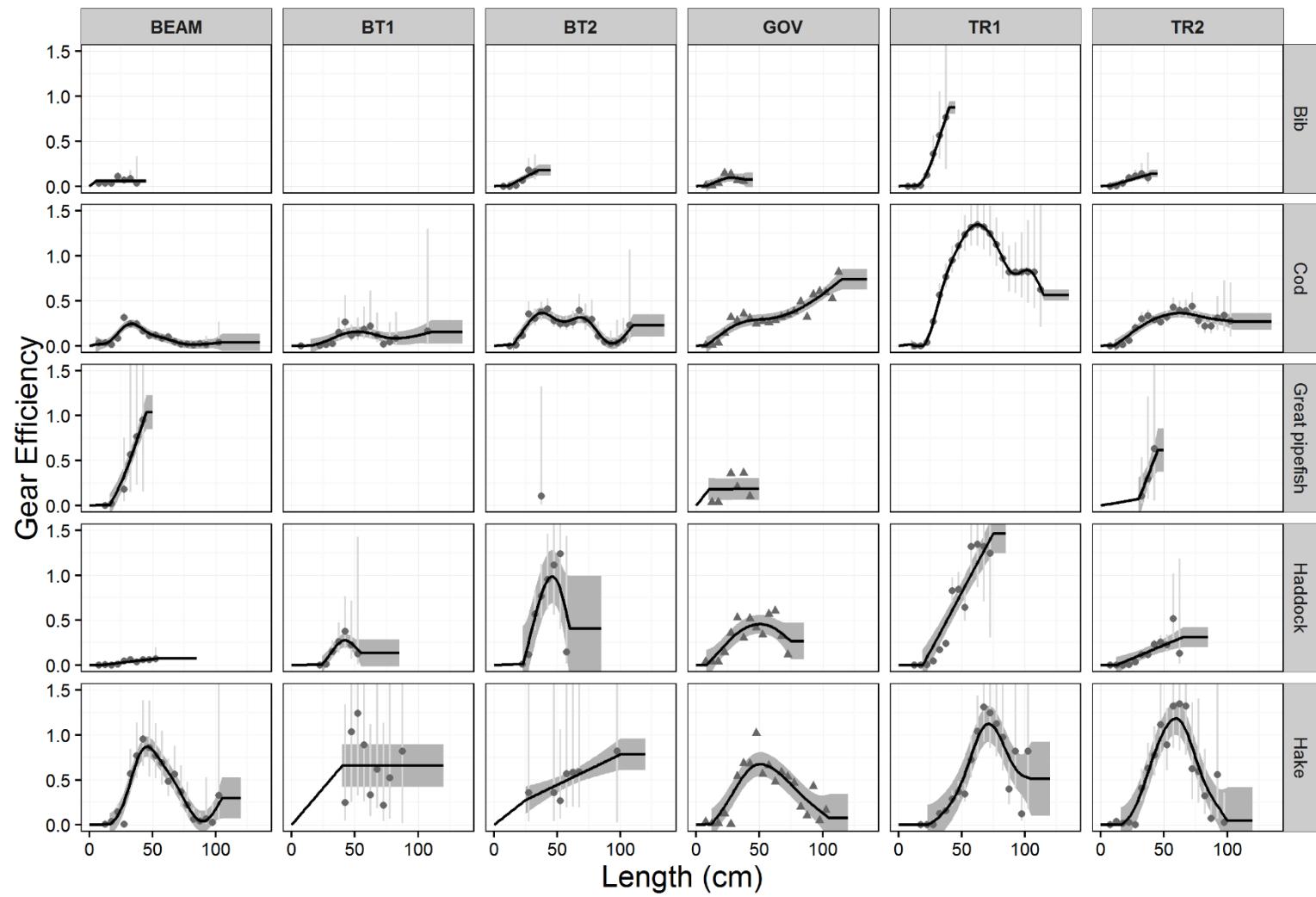


Figure S16. Relationships between gear efficiency and length for species in group 4. Vertical bars show 95% confidence intervals about estimates of absolute efficiency and shaded regions 95% confidence intervals about the fitted curves. Triangles indicate the reference gear used to derive catch ratios.

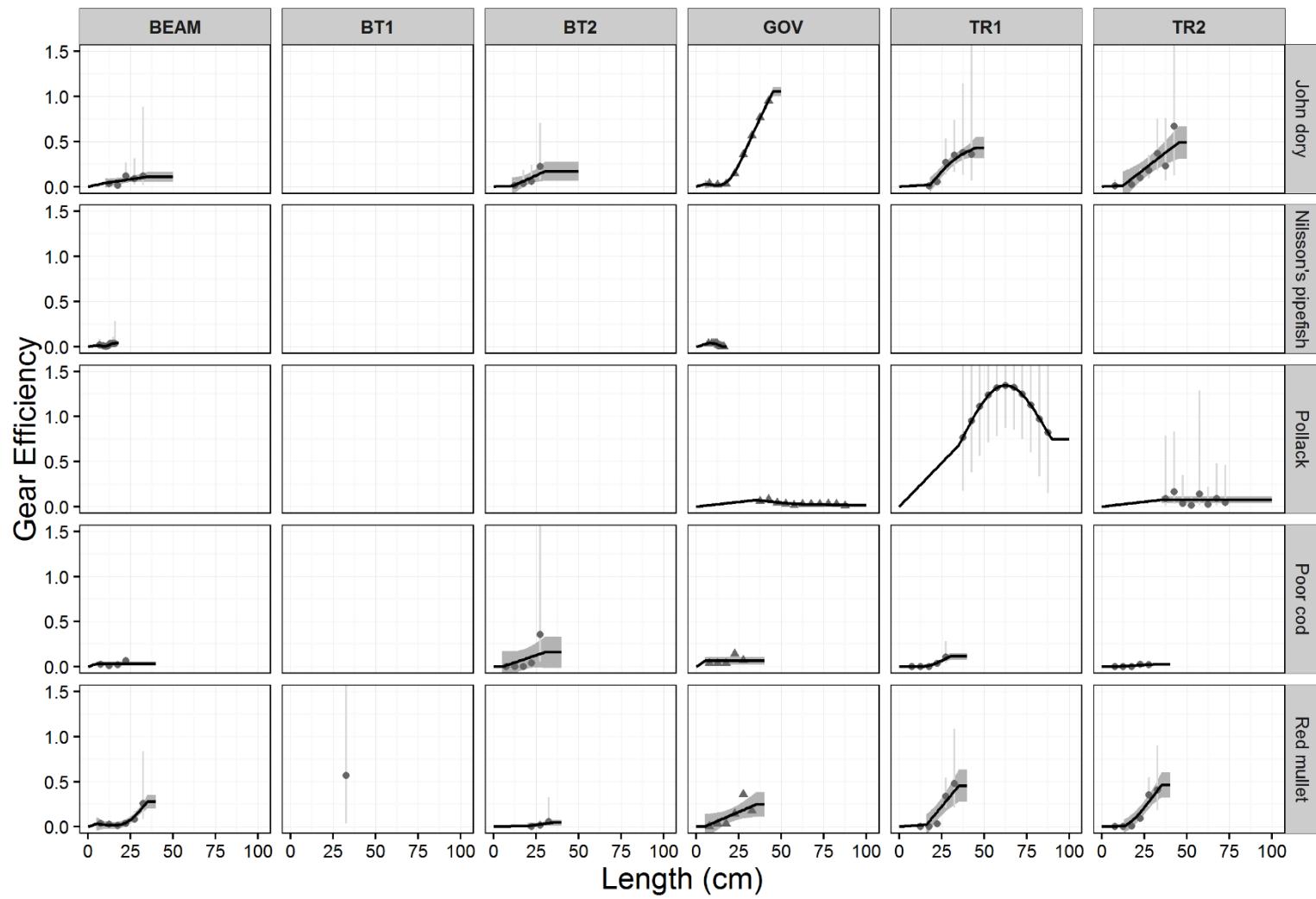


Figure S16 cont. Relationships between gear efficiency and length for species in group 4. Vertical bars show 95% confidence intervals about estimates of absolute efficiency and shaded regions 95% confidence intervals about the fitted curves. Triangles indicate the reference gear used to derive catch ratios.

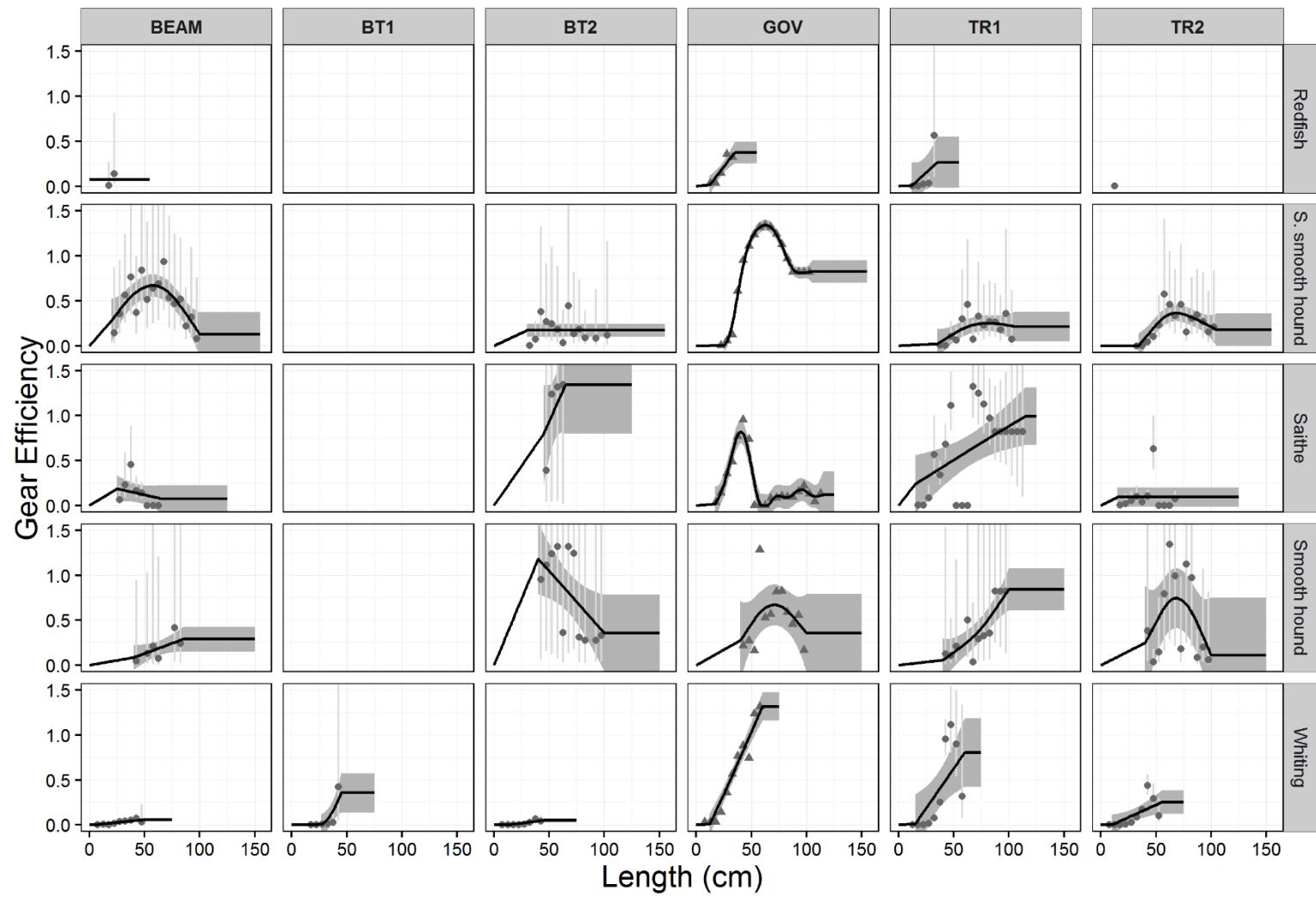


Figure S16 cont. Relationships between gear efficiency and length for species in group 4. Vertical bars show 95% confidence intervals about estimates of absolute efficiency and shaded regions 95% confidence intervals about the fitted curves. Triangles indicate the reference gear used to derive catch ratios.

S. smooth hound = Starry smooth hound

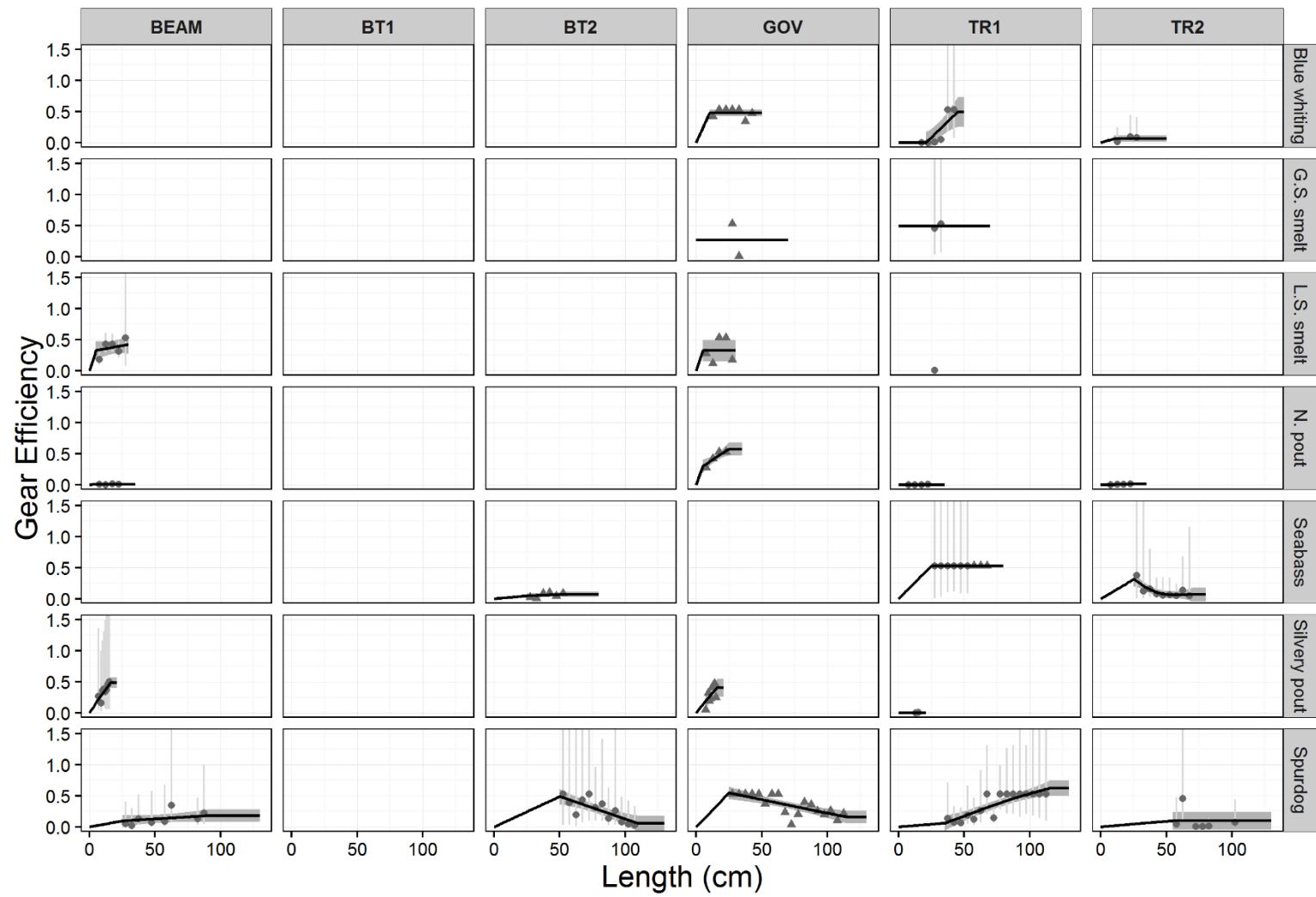


Figure S17. Relationships between gear efficiency and length for species in group 5. Vertical bars show 95% confidence intervals about estimates of absolute efficiency and shaded regions 95% confidence intervals about the fitted curves. Triangles indicate the reference gear used to derive catch ratios.

G. S. smelt = Great silver smelt; L. S. smelt = Lesser silver smelt; N. pout = Norway pout

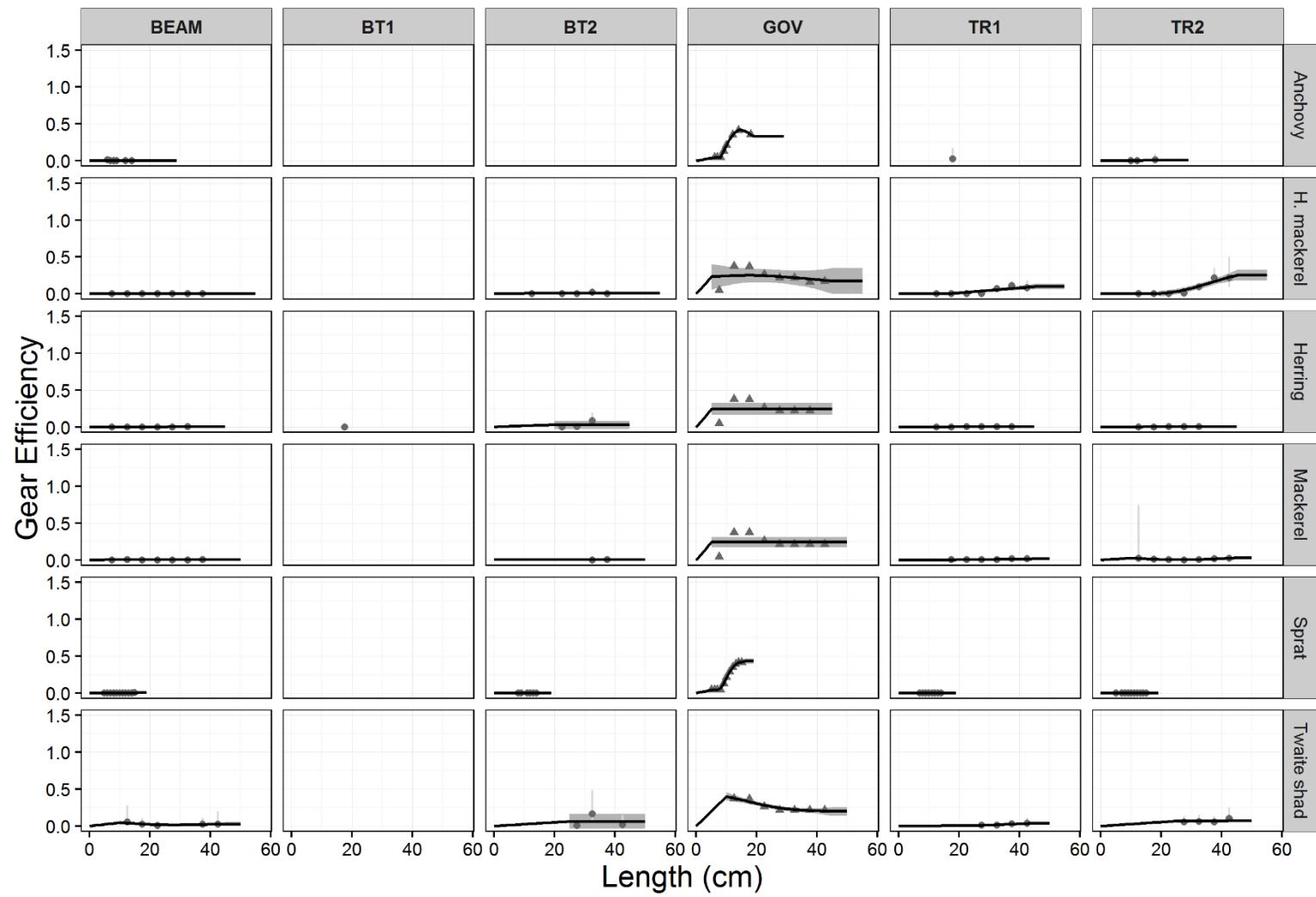


Figure S18. Relationships between gear efficiency and length for species in group 6. Vertical bars show 95% confidence intervals about estimates of absolute efficiency and shaded regions 95% confidence intervals about the fitted curves. Triangles indicate the reference gear used to derive catch ratios.

H. mackerel = Horse mackerel

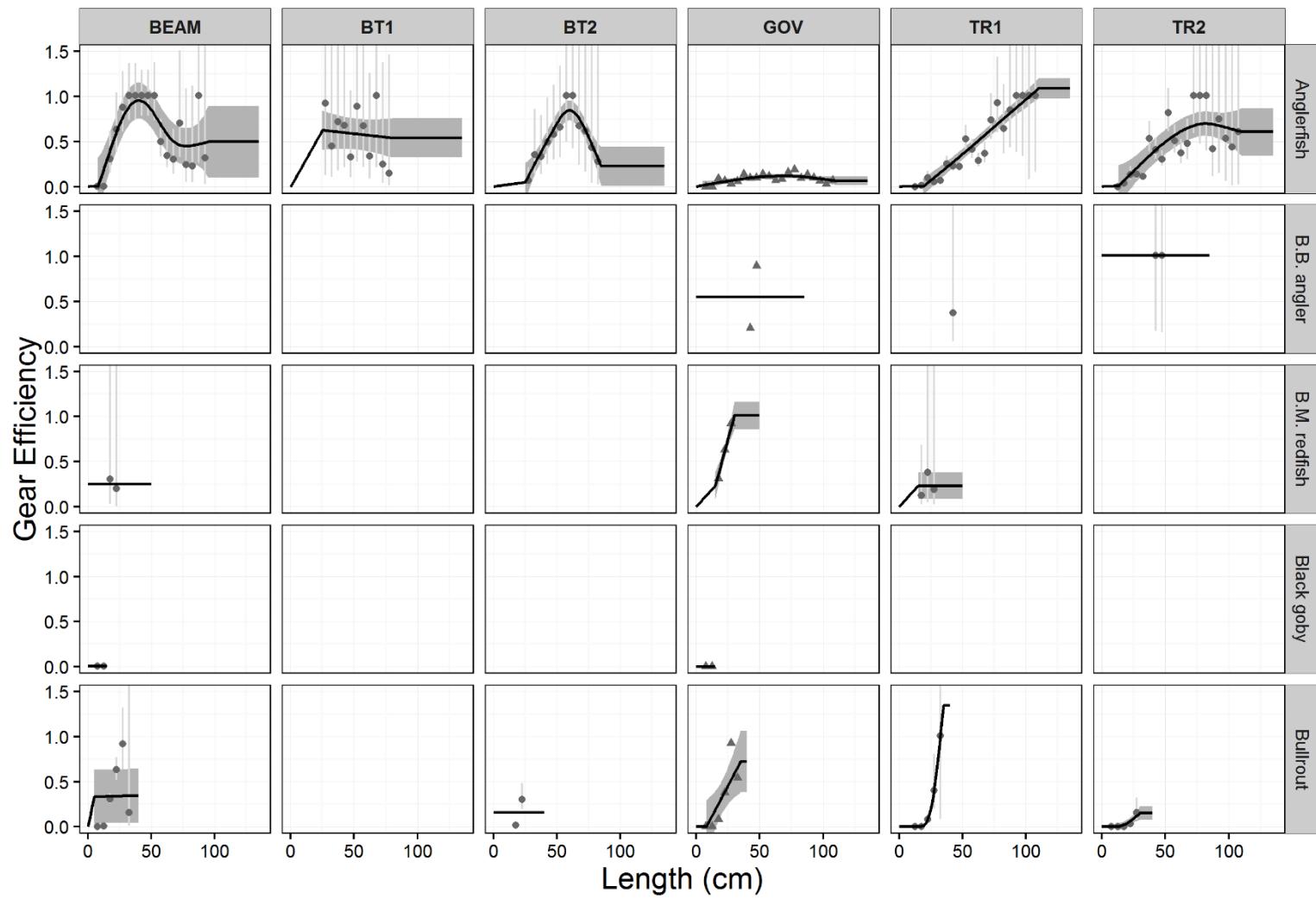


Figure S19. Relationships between gear efficiency and length for species in group 7. Vertical bars show 95% confidence intervals about estimates of absolute efficiency and shaded regions 95% confidence intervals about the fitted curves. Triangles indicate the reference gear used to derive catch ratios.

B. B. angler = Black-bellied angler; B. M. redfish = Blue-mouth redfish

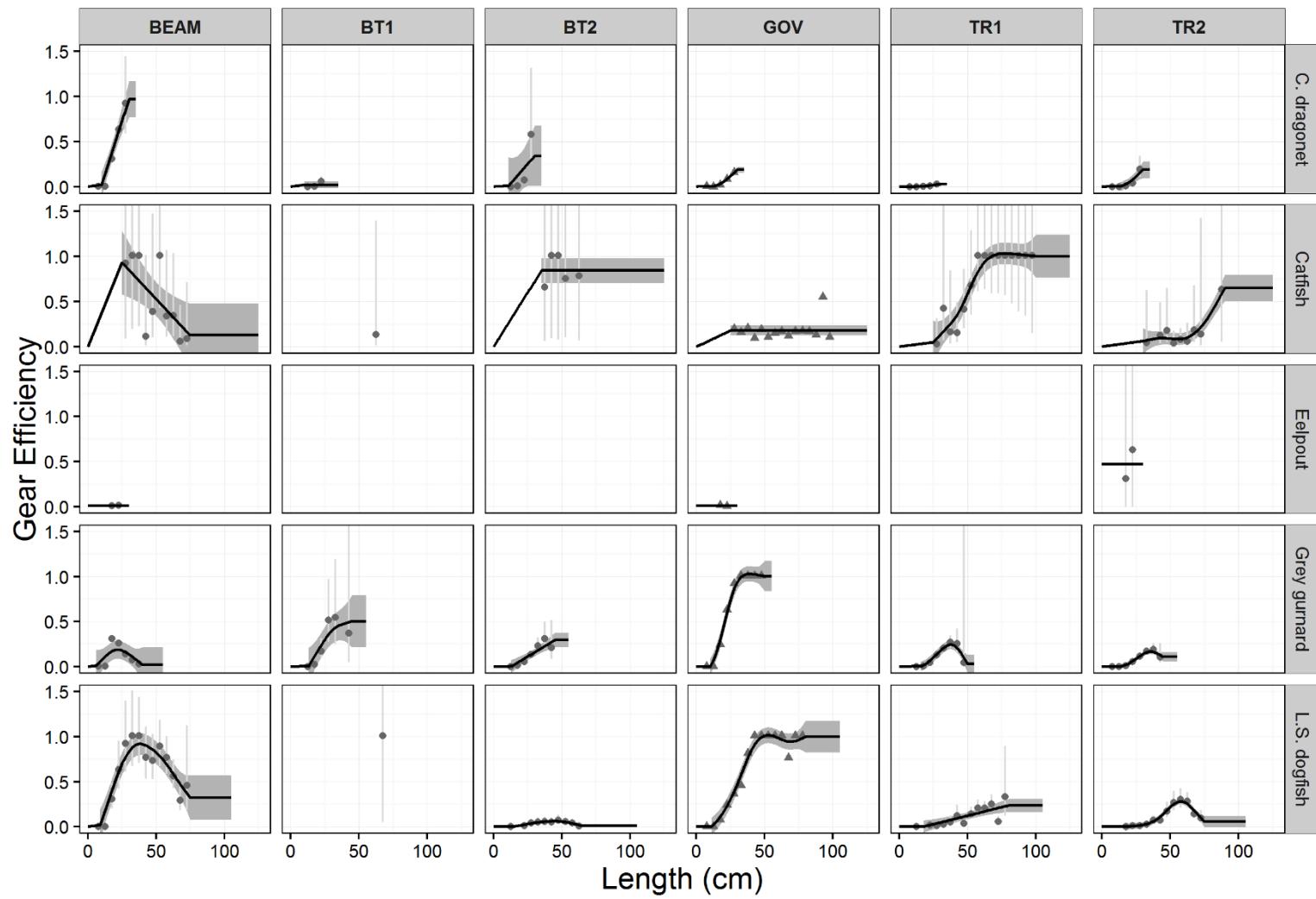


Figure S19 cont. Relationships between gear efficiency and length for species in group 7. Vertical bars show 95% confidence intervals about estimates of absolute efficiency and shaded regions 95% confidence intervals about the fitted curves. Triangles indicate the reference gear used to derive catch ratios.

C. dragonet = Common dragonet; L. S. dogfish = Lesser spotted dogfish

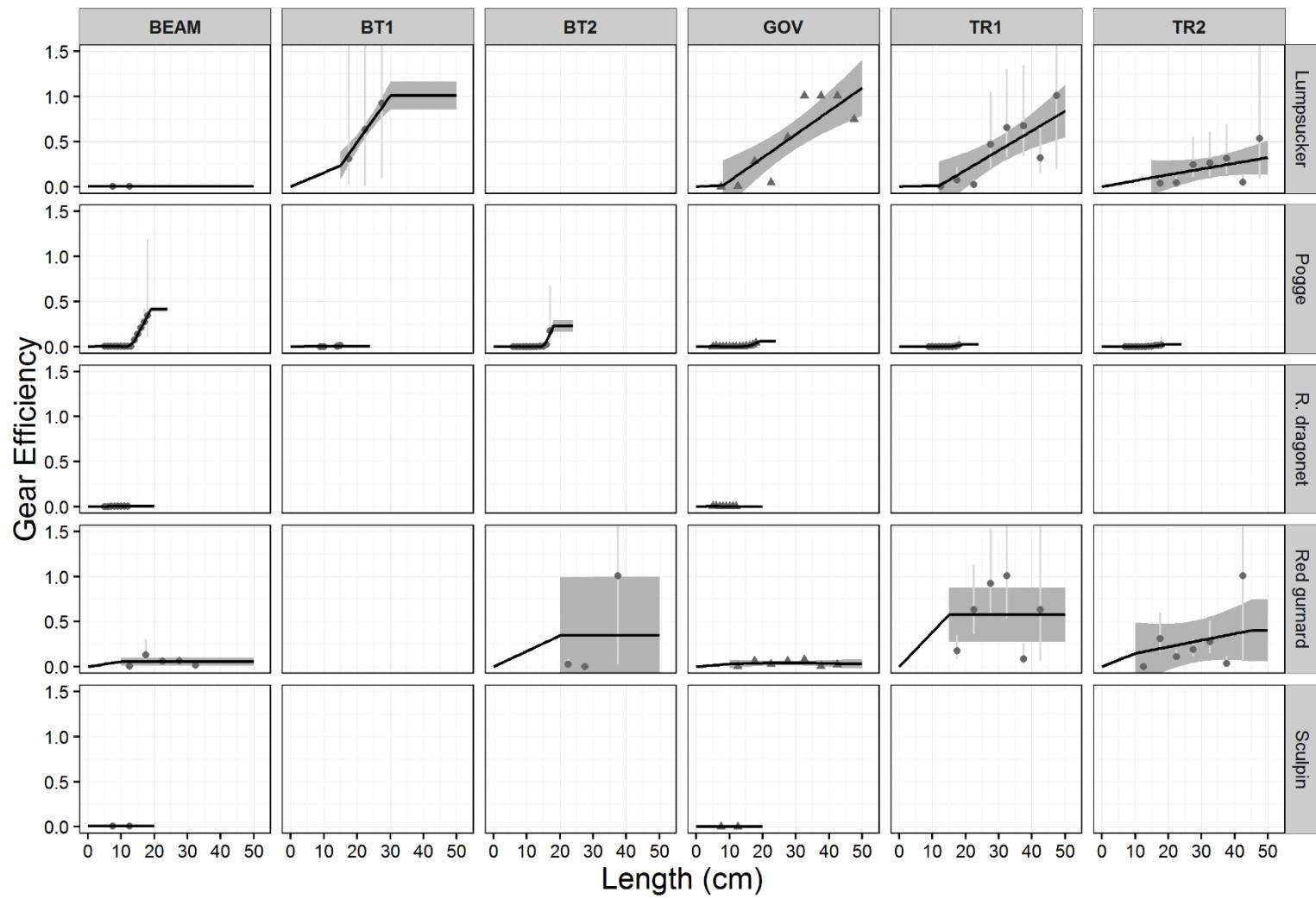


Figure S19 cont. Relationships between gear efficiency and length for species in group 7. Vertical bars show 95% confidence intervals about estimates of absolute efficiency and shaded regions 95% confidence intervals about the fitted curves. Triangles indicate the reference gear used to derive catch ratios.

R. dragonet = Reticulate dragonet

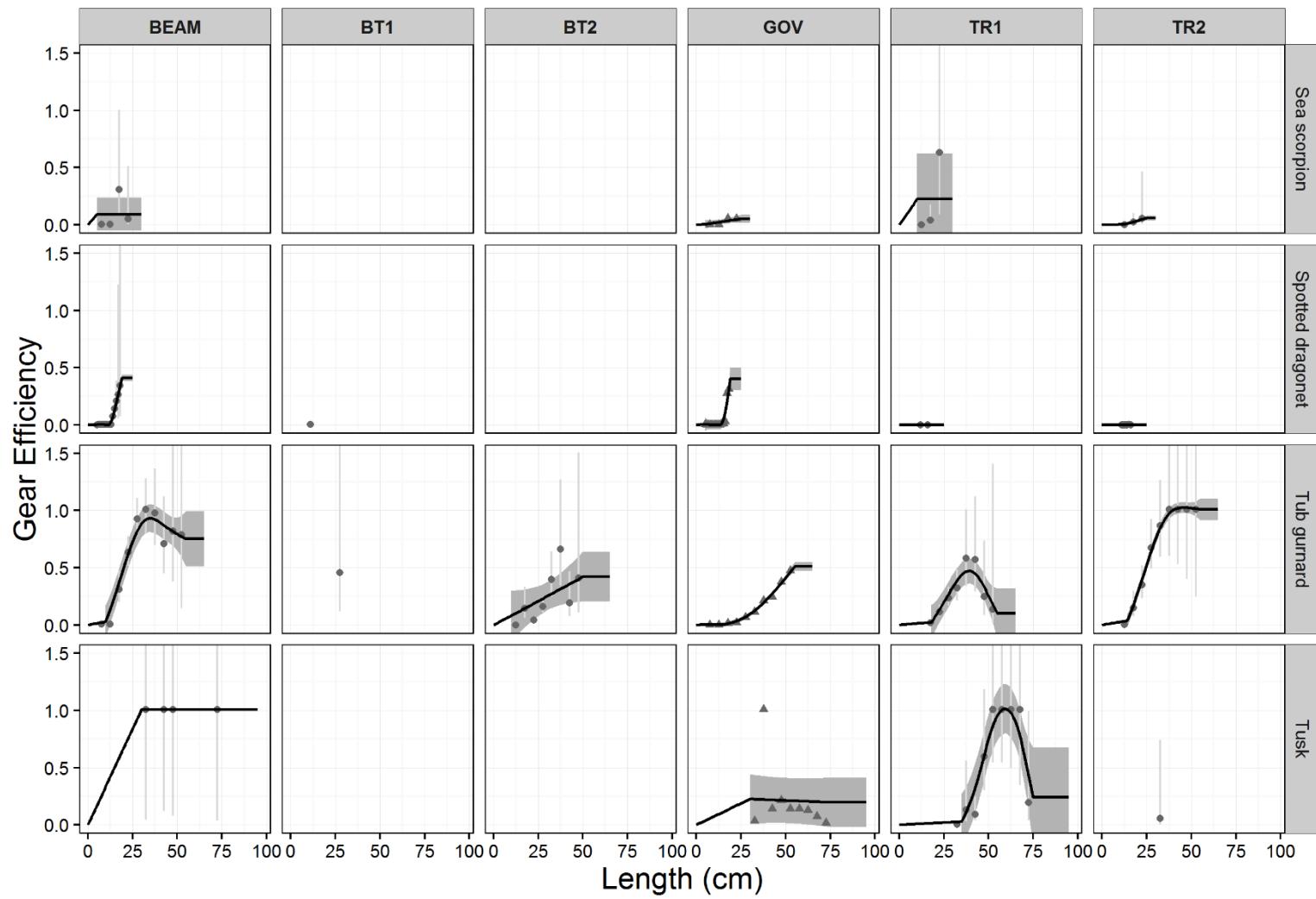


Figure S19 cont. Relationships between gear efficiency and length for species in group 7. Vertical bars show 95% confidence intervals about estimates of absolute efficiency and shaded regions 95% confidence intervals about the fitted curves. Triangles indicate the reference gear used to derive catch ratios.

Supplementary data file

The data file “EfficiencyTab.csv” comprises 1 row of headers and 53772 rows of data. Details of the file structure are provided in Table S6. Maximum sizes for each species are the maximum sizes recorded in the data rather than the maximum known size of the species.

Table S6. Details of variables in file “EfficiencyTab.csv”

Variable name	Variable definition	Units	Data type	Range of numeric values
Code	Species or species group (GRP). Codes following Table S1 and Table 2	NA	text	NA
Length	Length class to which efficiency estimate applies	cm	numeric	1 – 230
Gear	Gear type to which efficiency estimate applies. Codes in Table 1.	NA	text	NA
Species	Species common-name following Table S1	NA	text	NA
Group	Groups to which species are assigned following Table S1	NA	text	NA
Ref	Indicates when a gear listed under “Gear” was adopted as the reference gear	NA	text	NA
Absolute	Absolute efficiency estimate for the species group and length class	proportion	numeric	$1.1765 \times 10^{-7} – 1.3449$
Abs.l.95	Lower 95% confidence interval for absolute efficiency estimate	proportion	numeric	$4.1002 \times 10^{-9} – 1.1356$
Abs.u.95	Upper 95% confidence interval for absolute efficiency estimate	proportion	numeric	$6.5685 \times 10^{-7} – 3.9034 \times 10^6$
Efficiency	Efficiency estimate for species or species group and length class	proportion	numeric	0 – 1.4643
Eff.l.95	Lower 95% confidence interval for the efficiency estimate	proportion	numeric	-0.5267 – 1.3425
Eff.u.95	Upper 95% confidence interval for the efficiency estimate	proportion	numeric	0 – 1.8929

References

Fraser, H. M., Greenstreet, S. P. R., and Piet, G. J. 2007. Taking account of catchability in groundfish survey trawls: implications for estimating demersal fish biomass. *ICES Journal of Marine Science*, 64: 1800–1819.