The consequences of open-cage, sea-based fish farming

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Iceland 14th March

- Brief history of sea lice (*L.salmonis*) impacts on sea trout in Ireland
- Recent evidence of sea lice impact on salmon
- Lessons learnt regarding farm management practice and impacts of sea lice
- Future prospects for interaction of farmed & wild fish

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Experience in Ireland

- Development of a marine salmon farming industry in the 1980’s
- Premature return of sea trout with heavy lice infestations mostly juvenile lice
- Collapse in sea trout stocks in aquaculture bays

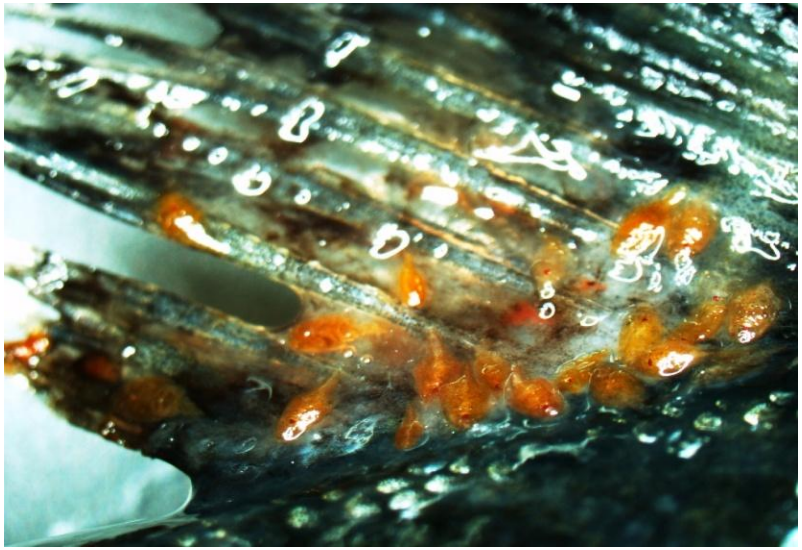
Source of lice

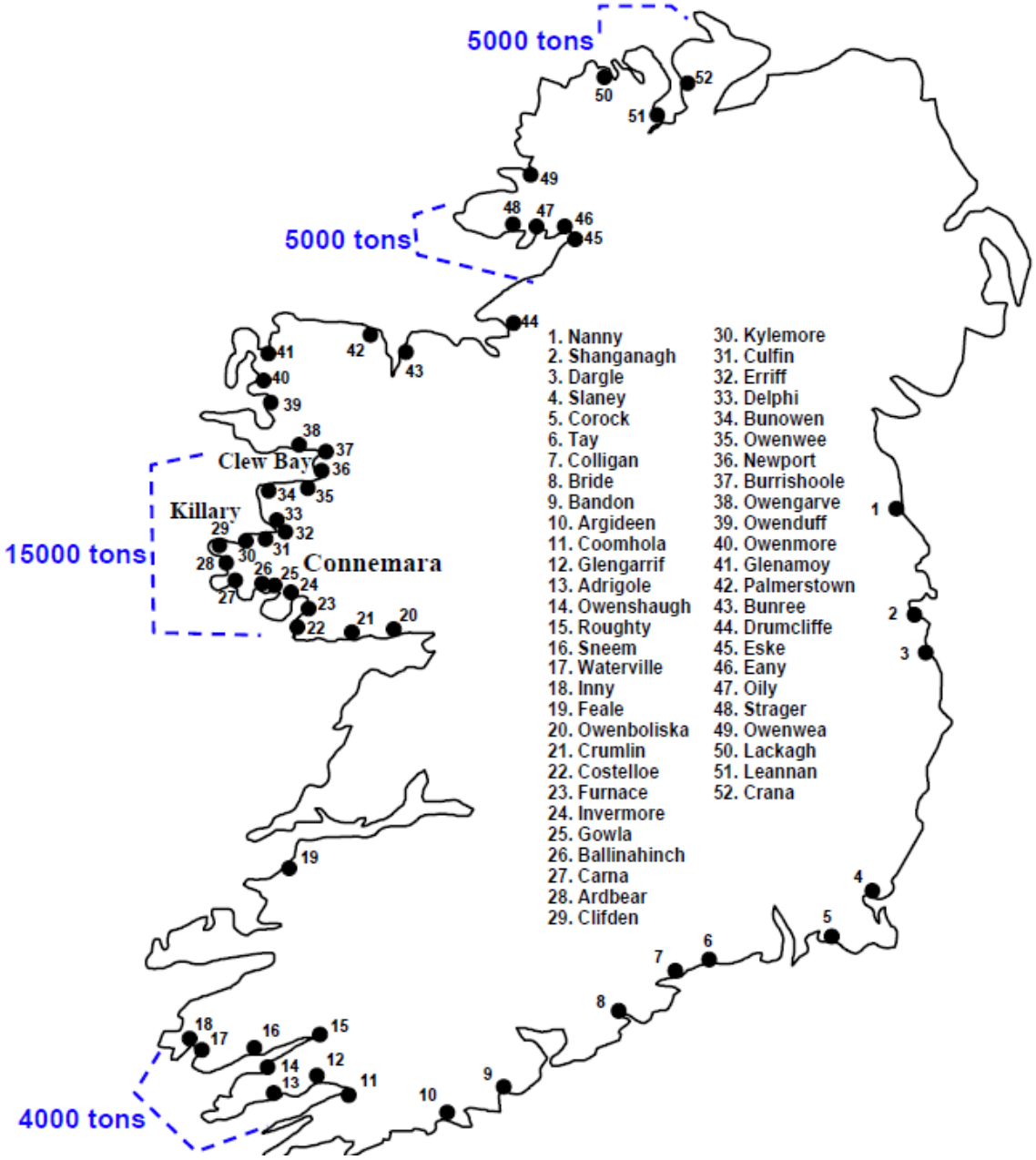
- Studies show >95% of lice originated from salmon farms
- Spring returning salmon and sea trout not correlated to lice infestation on sea trout post smolts
- Lice infestations predominantly juvenile lice

Juvenile lice infestation of sea trout

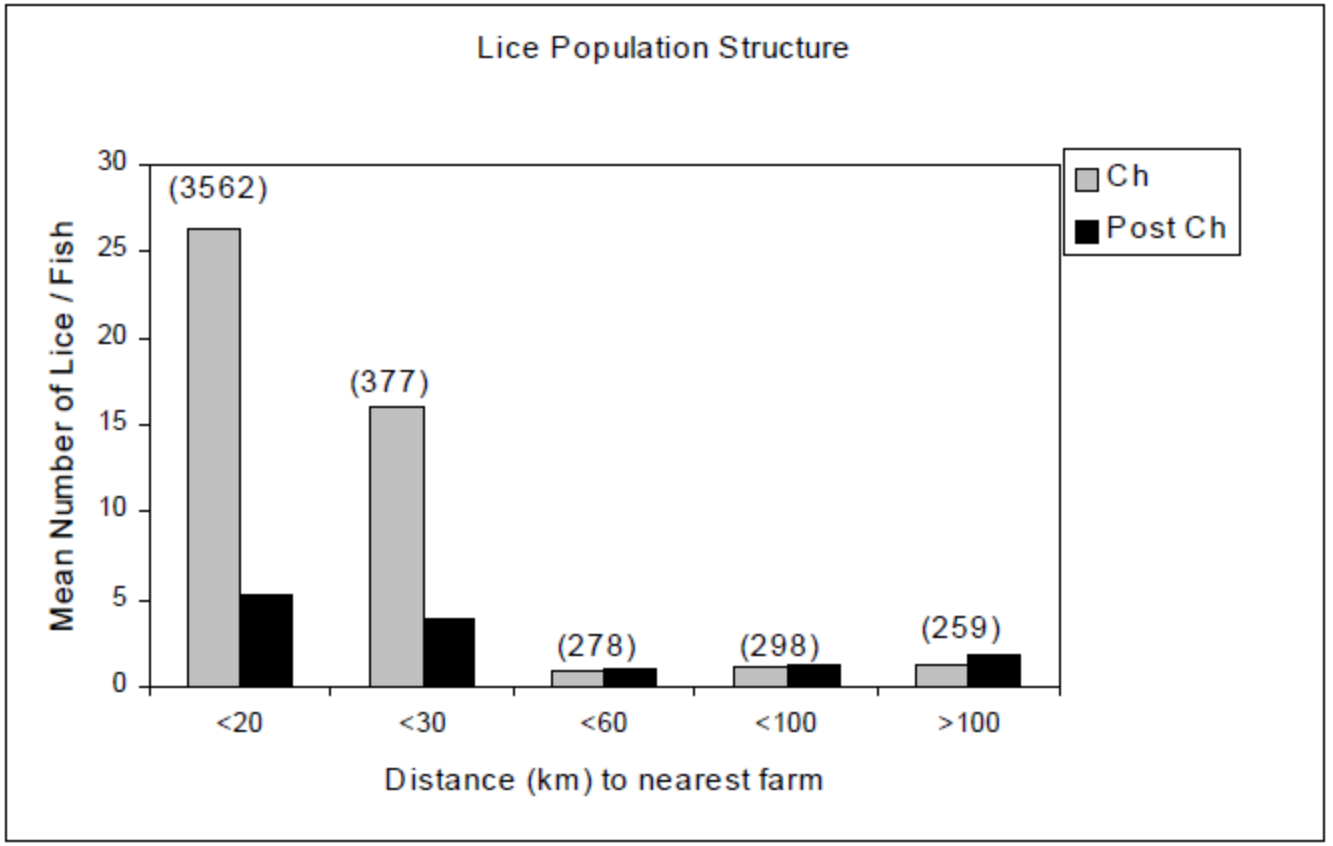
Experience in Ireland

- Heavy sea lice infestation on sea trout
- A correlation between sea lice levels on sea trout and distance to salmon farms
- Linked with the development of marine salmon farming in the mid-west zone, (Tully el al, 1999, Gargan et al., 2003).

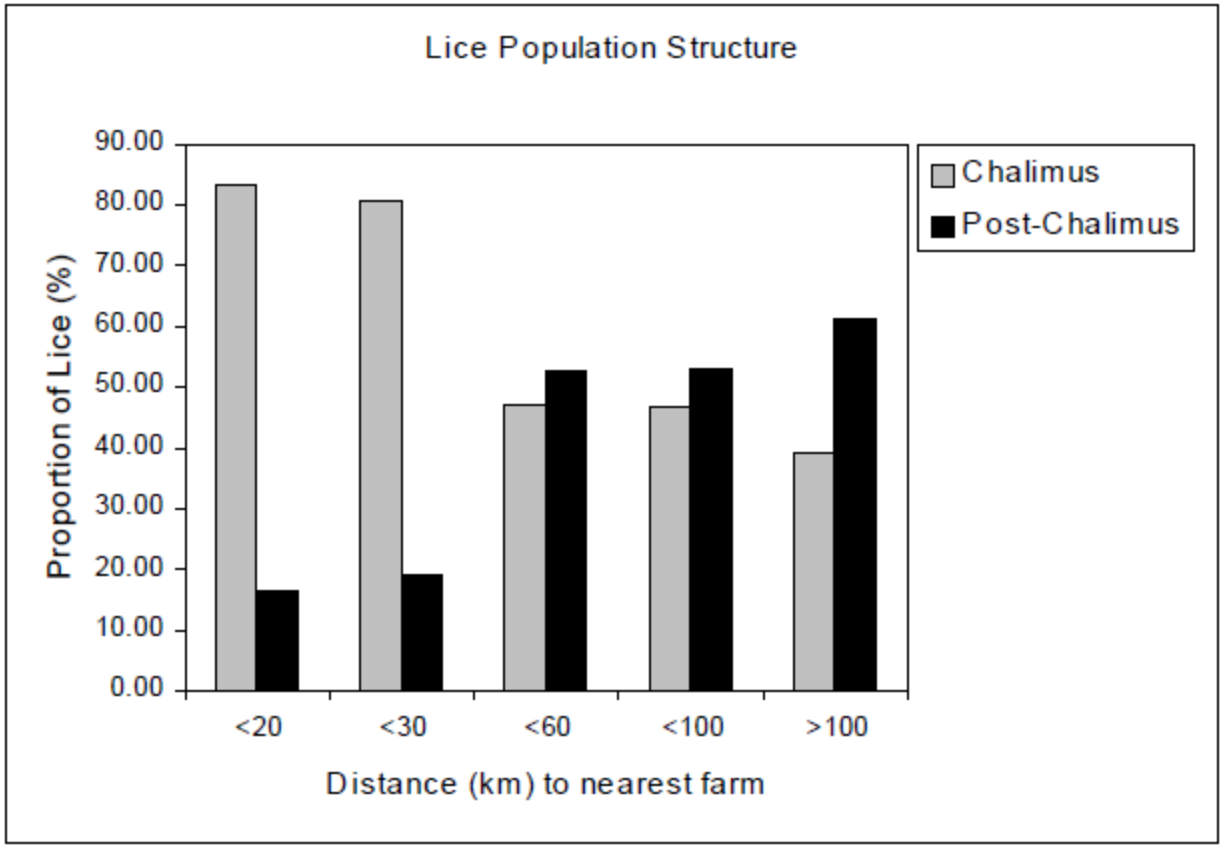



5000 tons
5000 tons
15000 tons
4000 tons
Clew Bay
Killary
Connemara
1. Nanny
2. Shanganagh
3. Dargle
4. Slaney
5. Corock
6. Tay
7. Colligan
8. Bride
9. Bandon
10. Argideen
11. Coomhola
12. Glengarrif
13. Adrigole
14. Owenshaugh
15. Roughty
16. Sneem
17. Waterville
18. Inny
19. Feale
20. Owenboliska
21. Crumlin
22. Costelloe
23. Furnace
24. Invermore
25. Gowla
26. Ballinahinch
27. Carna
28. Ardbear
29. Clifden
30. Kylemore
31. Culfin
32. Erriff
33. Delphi
34. Bunowen
35. Owenwee
36. Newport
37. Burrishoole
38. Owengarve
39. Owenduff
40. Owenmore
41. Glenamoy
42. Palmerstown
43. Bunree
44. Drumcliffe
45. Eske
46. Eany
47. Oily
48. Strager
49. Owenwea
50. Lackagh
51. Leannan
52. Crana

Sea lice level & distance to salmon farms



Lice stage v distance to farms



The % risk of physiological stress (fish with >55 lice)

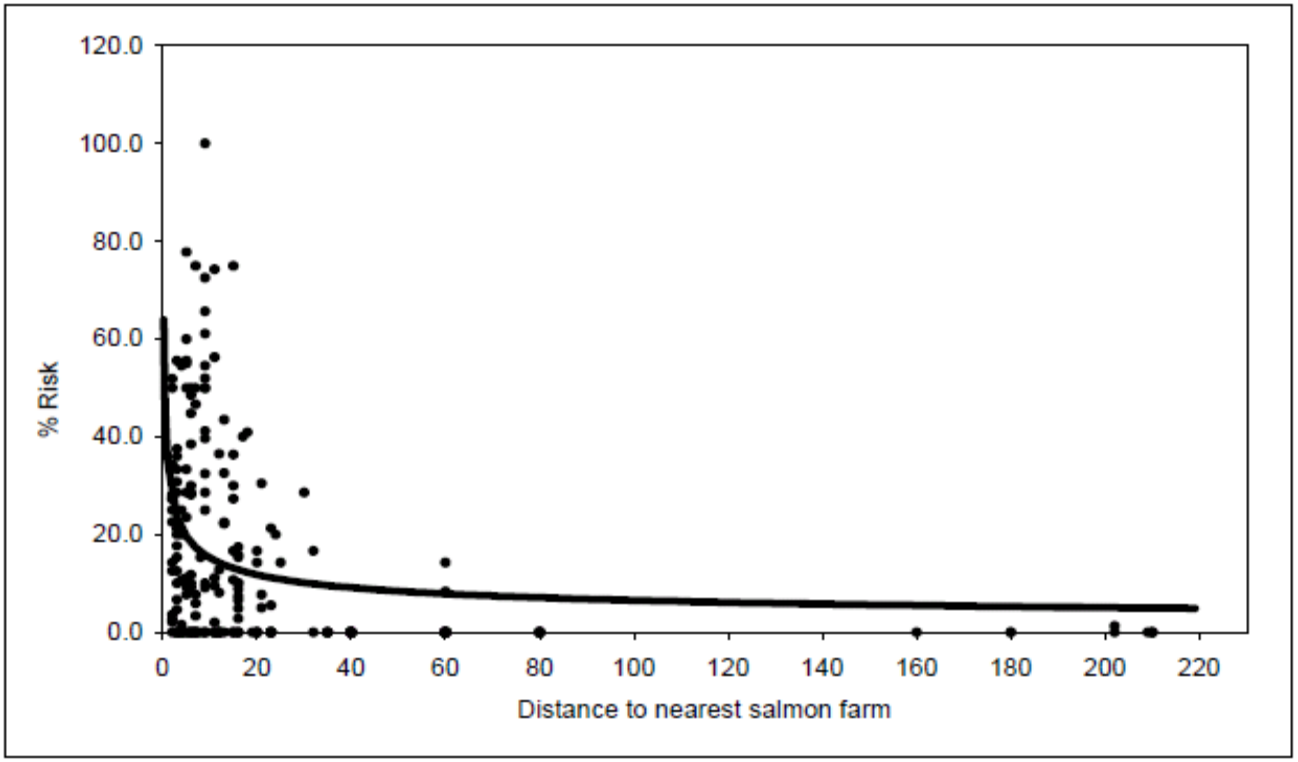
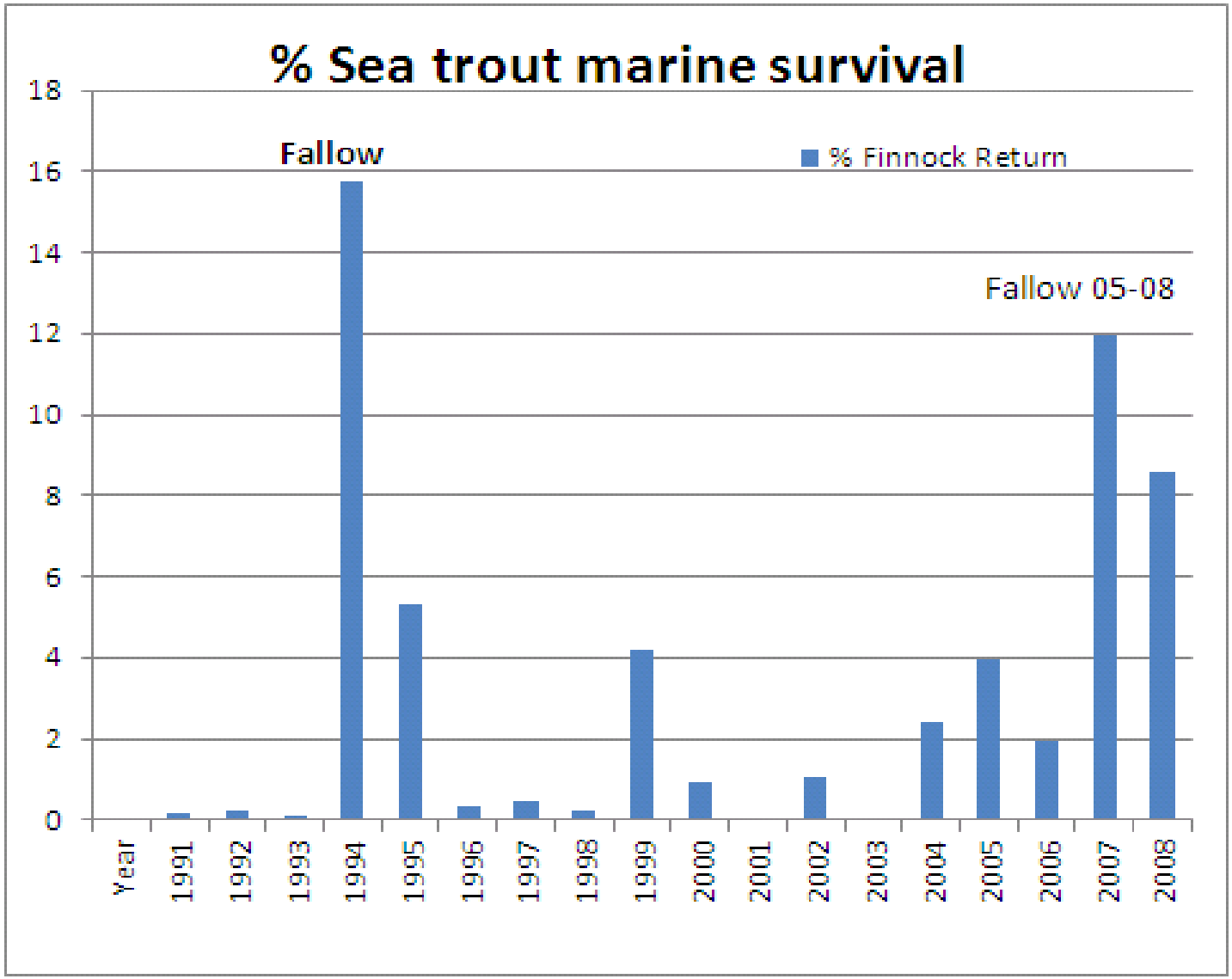
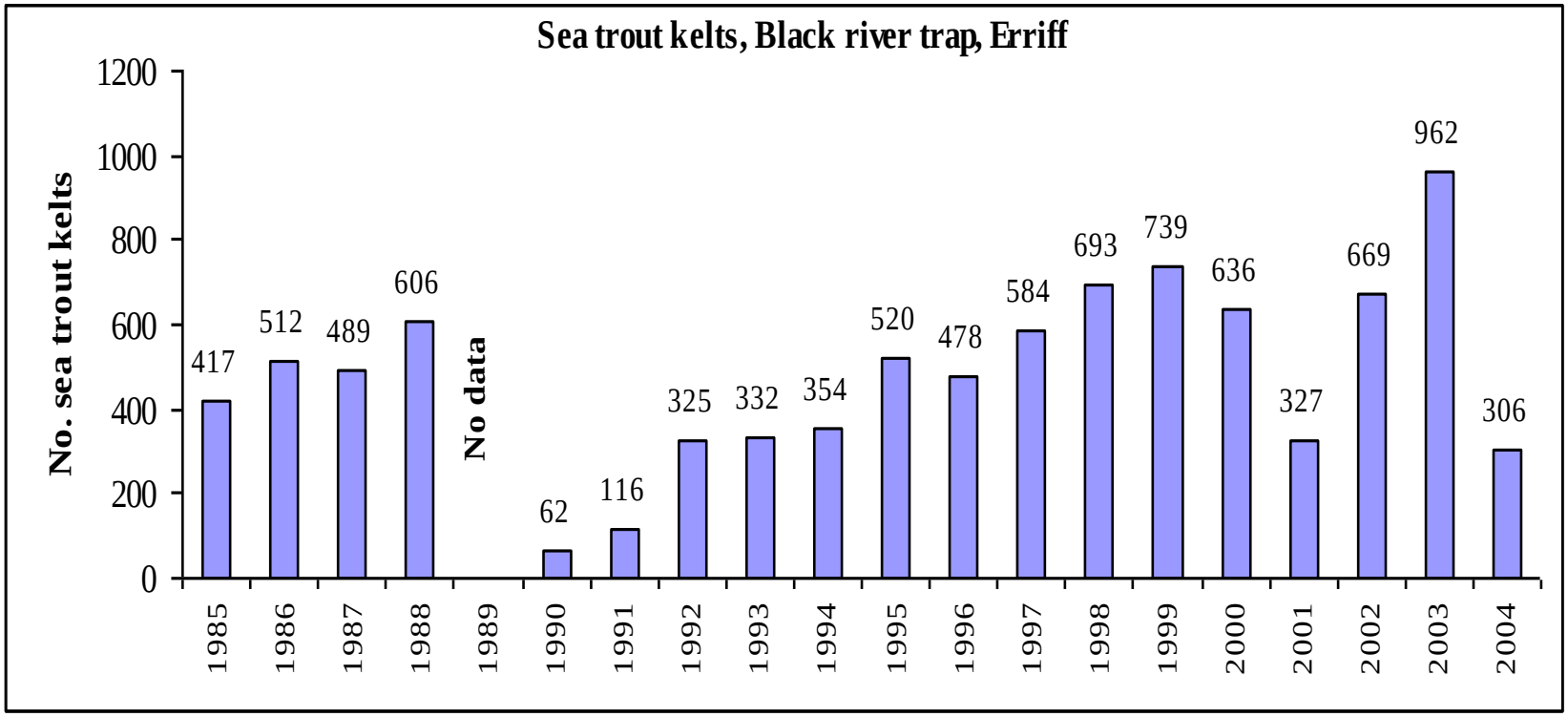
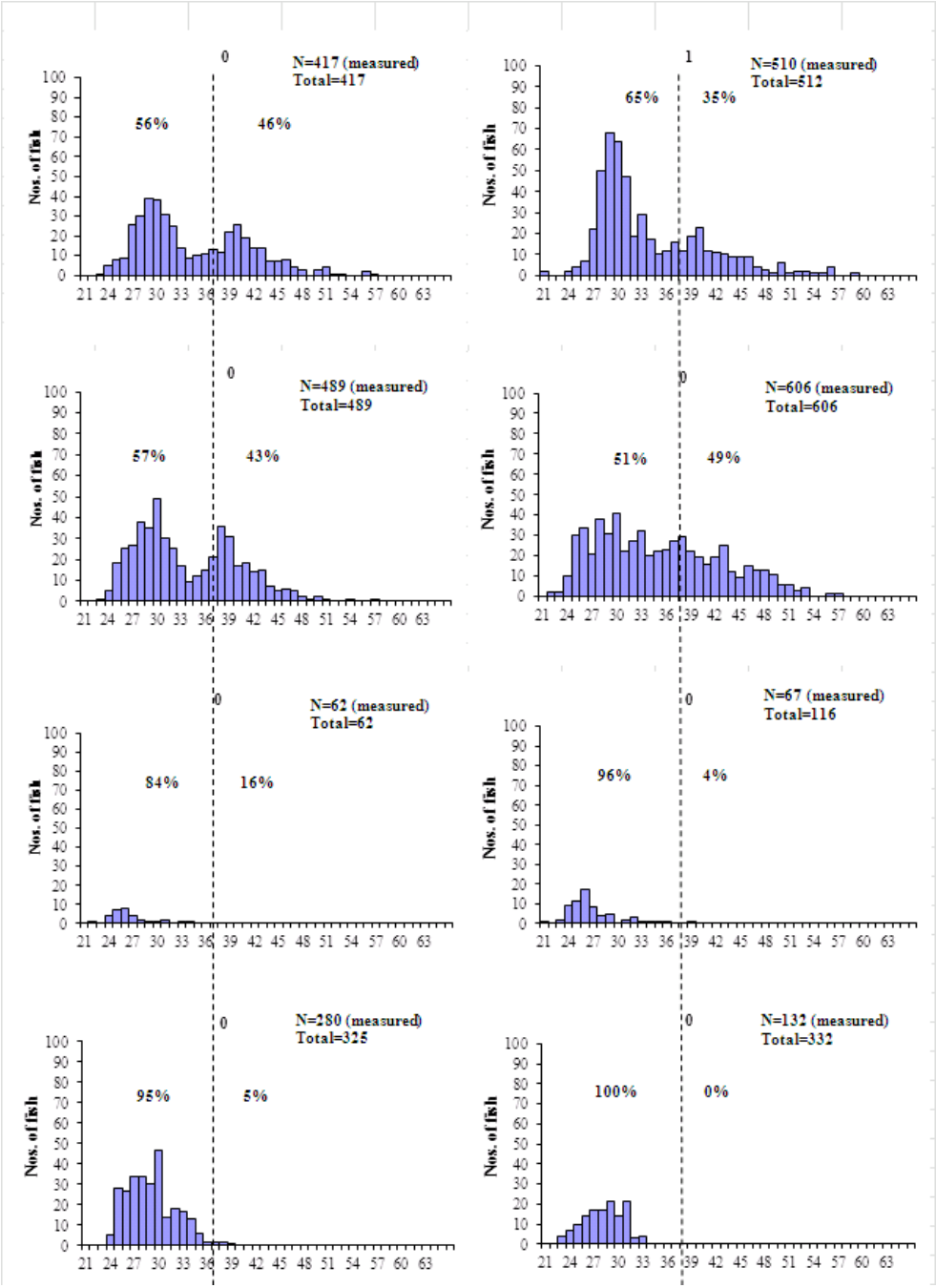


Fig. 6. The relationship between the %risk (number of fish with more than 55 lice per fish / total sample (N)) and distance (km) to the nearest marine salmon farm. A power function of the form % Risk = 35.4*Distance^-0.3670 is fitted to the data.


% Sea trout marine survival
Fallow
% Finnock Return
Fallow 05-08
18
16
14
12
10
8
6
4
2
0
Year
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008


Sea trout kelts, Black river trap, Erriff
No. sea trout kelts
1200
1000
800
600
400
200
0
417
512
489
606
No data
62
116
325
332
354
520
478
584
693
739
636
327
669
962
306
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004


0
N=417 (measured)
Total=417
56%
46%
Nos. of fish
1
N=510 (measured)
Total=512
65%
35%
0
N=489 (measured)
Total=489
57%
43%
0
N=606 (measured)
Total=606
51%
49%
0
N=62 (measured)
Total=62
84%
16%
0
N=67 (measured)
Total=116
96%
4%
0
N=280 (measured)
Total=325
95%
5%
0
N=132 (measured)
Total=332
100%
0%
21 24 27 30 33 36 39 42 45 48 51 54 57 60 63

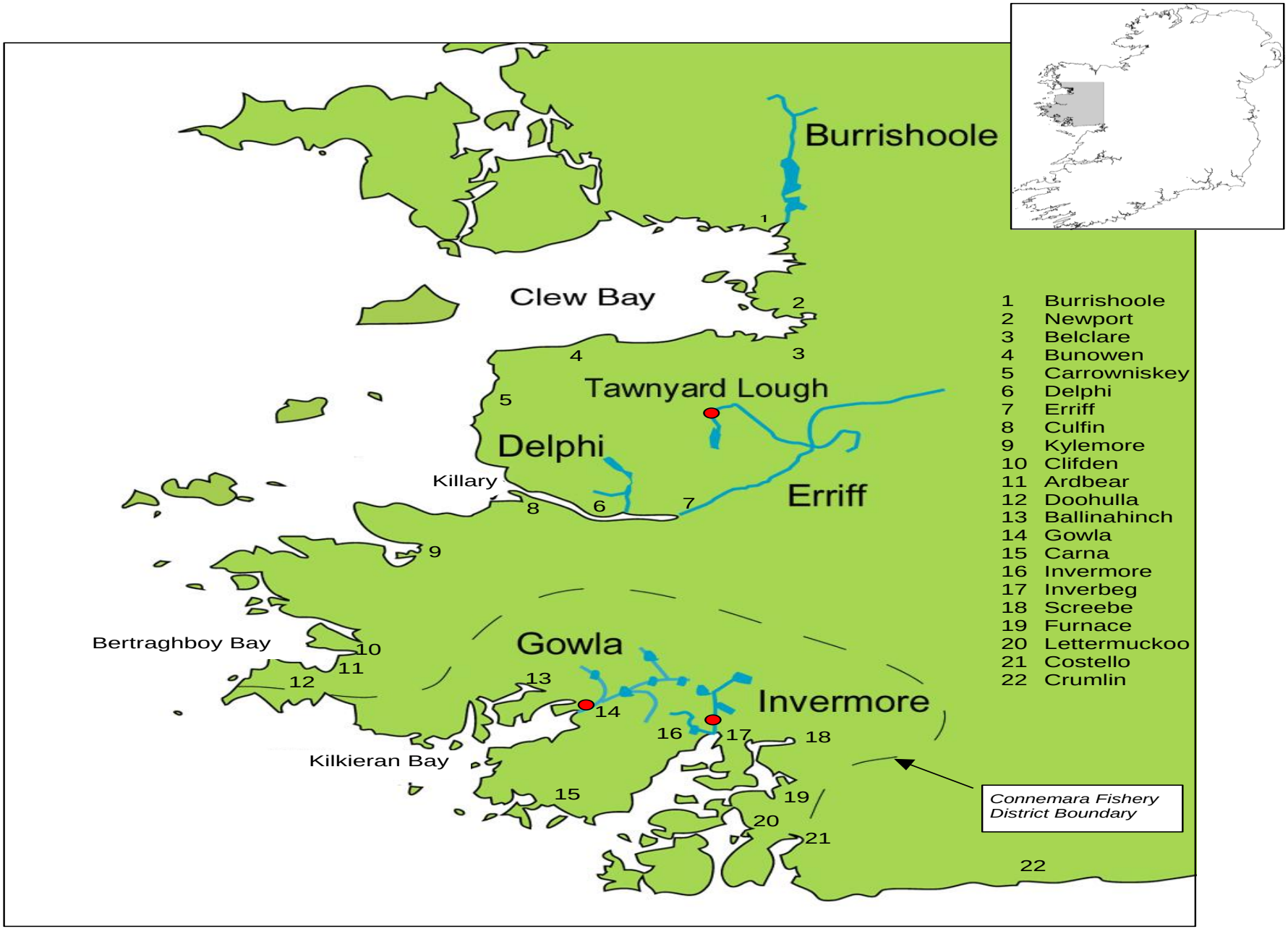
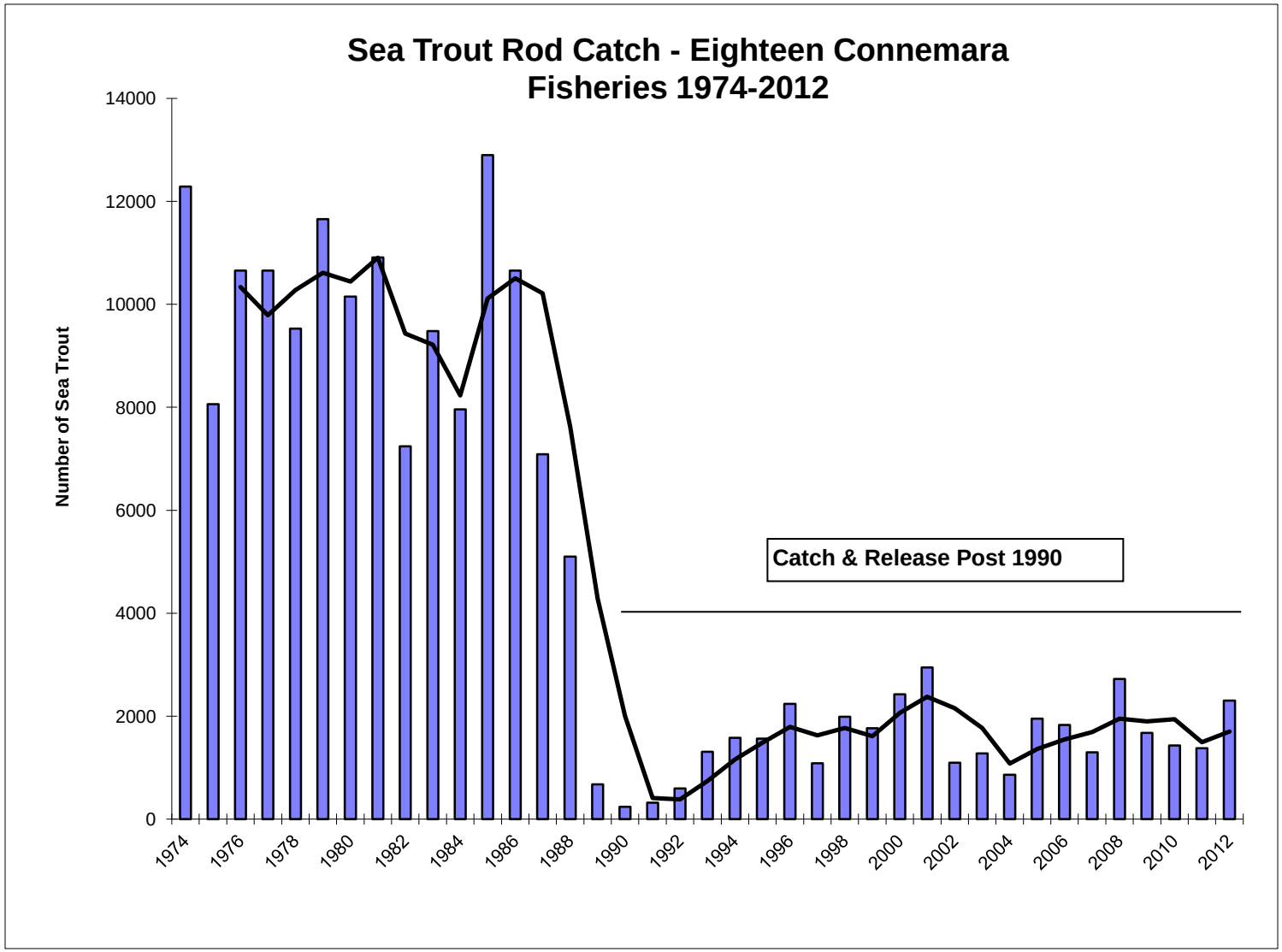
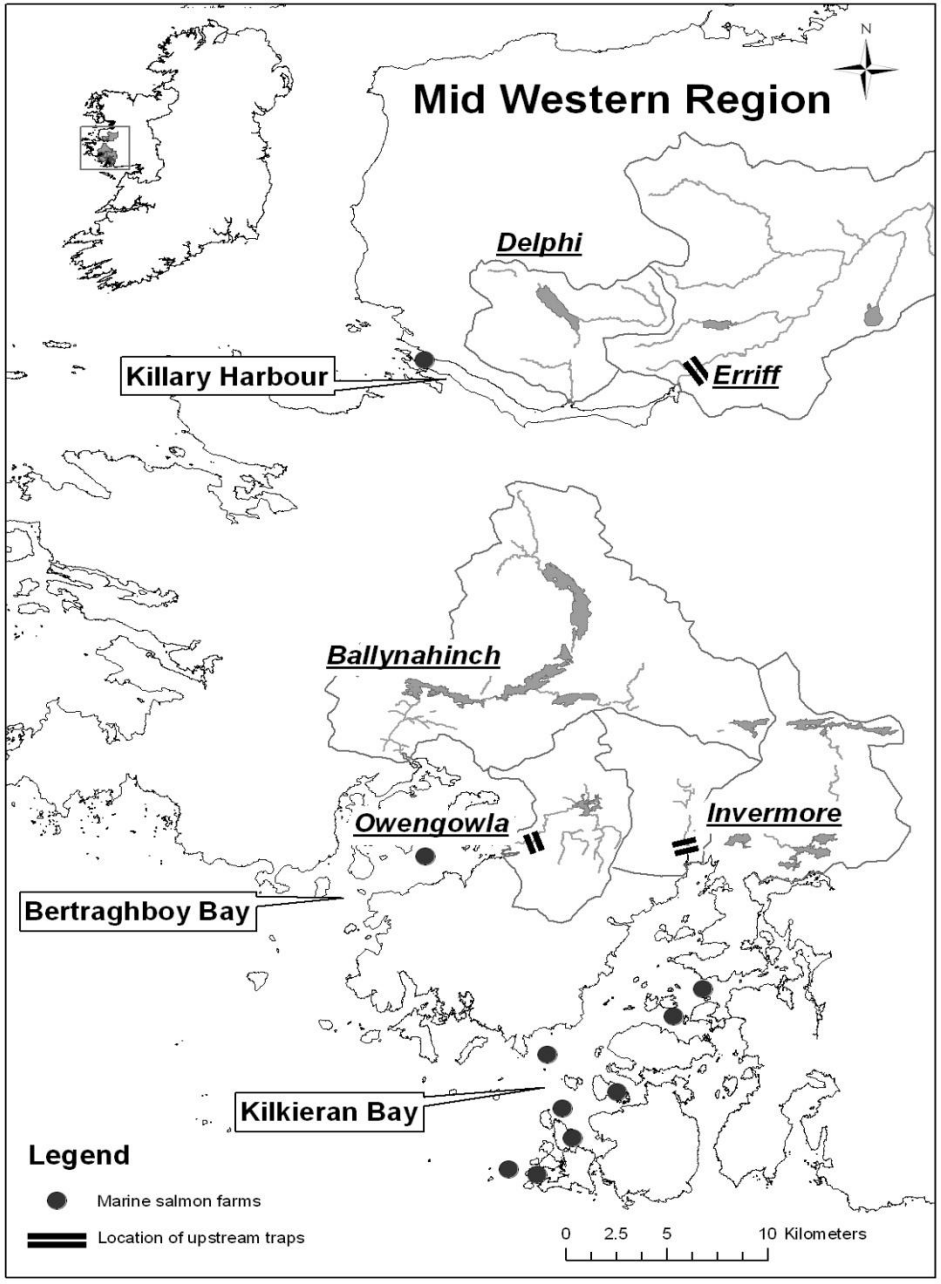
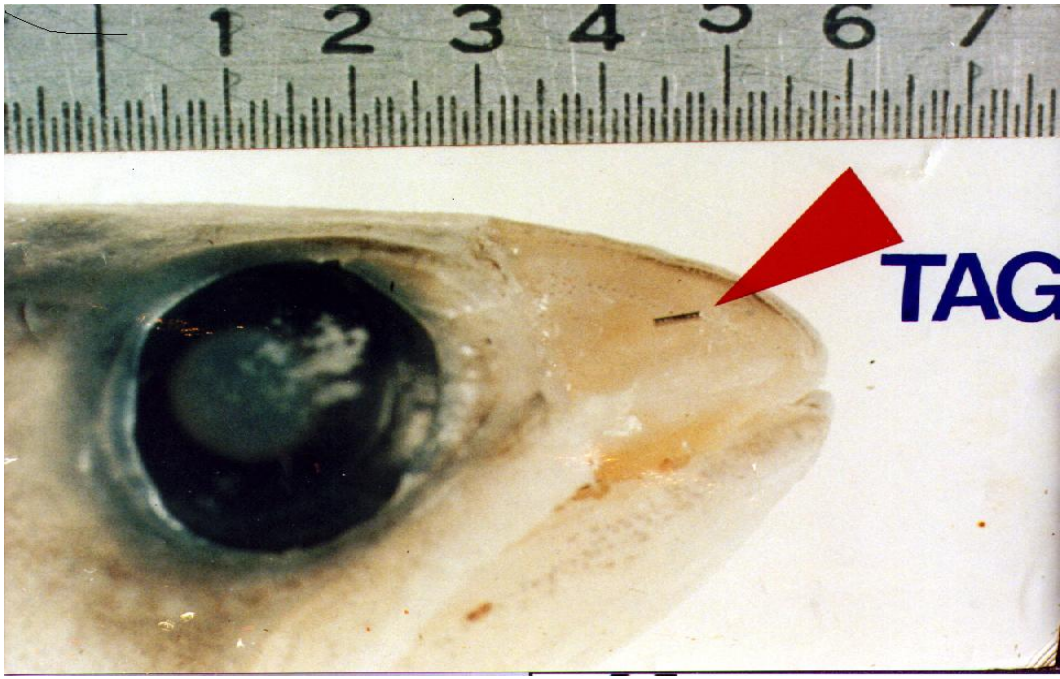


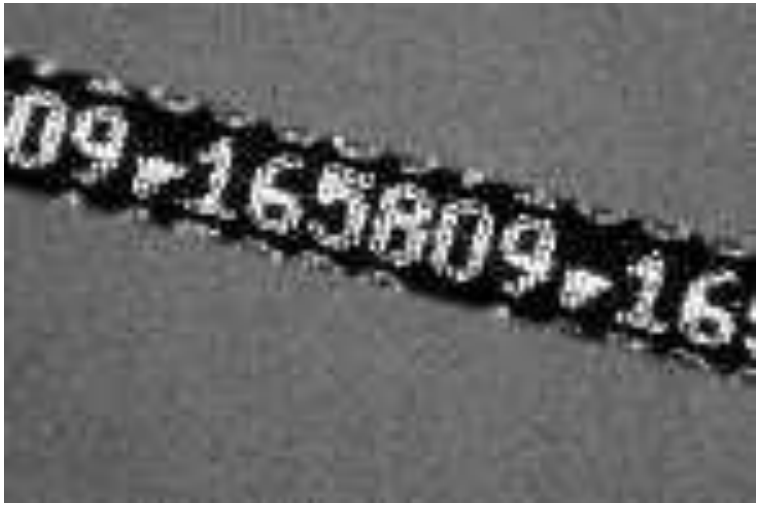
Fig 1. Location of Mid Western Sea-trout Fisheries, and trapping locations (●).


Sea Trout Rod Catch - Eighteen Connemara Fisheries 1974-2012
Number of Sea Trout
14000
12000
10000
8000
6000
4000
2000
0
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
Catch & Release Post 1990

Are salmon smolts less likely to be impacted by lice?


Mid Western Region
N
Delphi
Killary Harbour
Erriff
Ballynahinch
Owengowla
Invermore
Bertraghboy Bay
Kilkieran Bay
Legend
Marine salmon farms
Location of upstream traps
0 2.5 5 10 Kilometers


1 2 3 4 5 6 7
TAG



Lice Impact on Atlantic Salmon Smolts

- 2012 paper published in;
- *Canadian Journal of Fisheries & Aquatic Science*

- **Evidence for sea lice-induced marine mortality of Atlantic salmon (*Salmo salar* L.) in western Ireland from experimental releases of ranched smolts treated with emamectin benzoate.**

P. Gargan & G. Forde, Inland Fisheries Ireland

C. Todd & N. Hazon, Scottish Oceans Institute, University of St Andrews, Scotland

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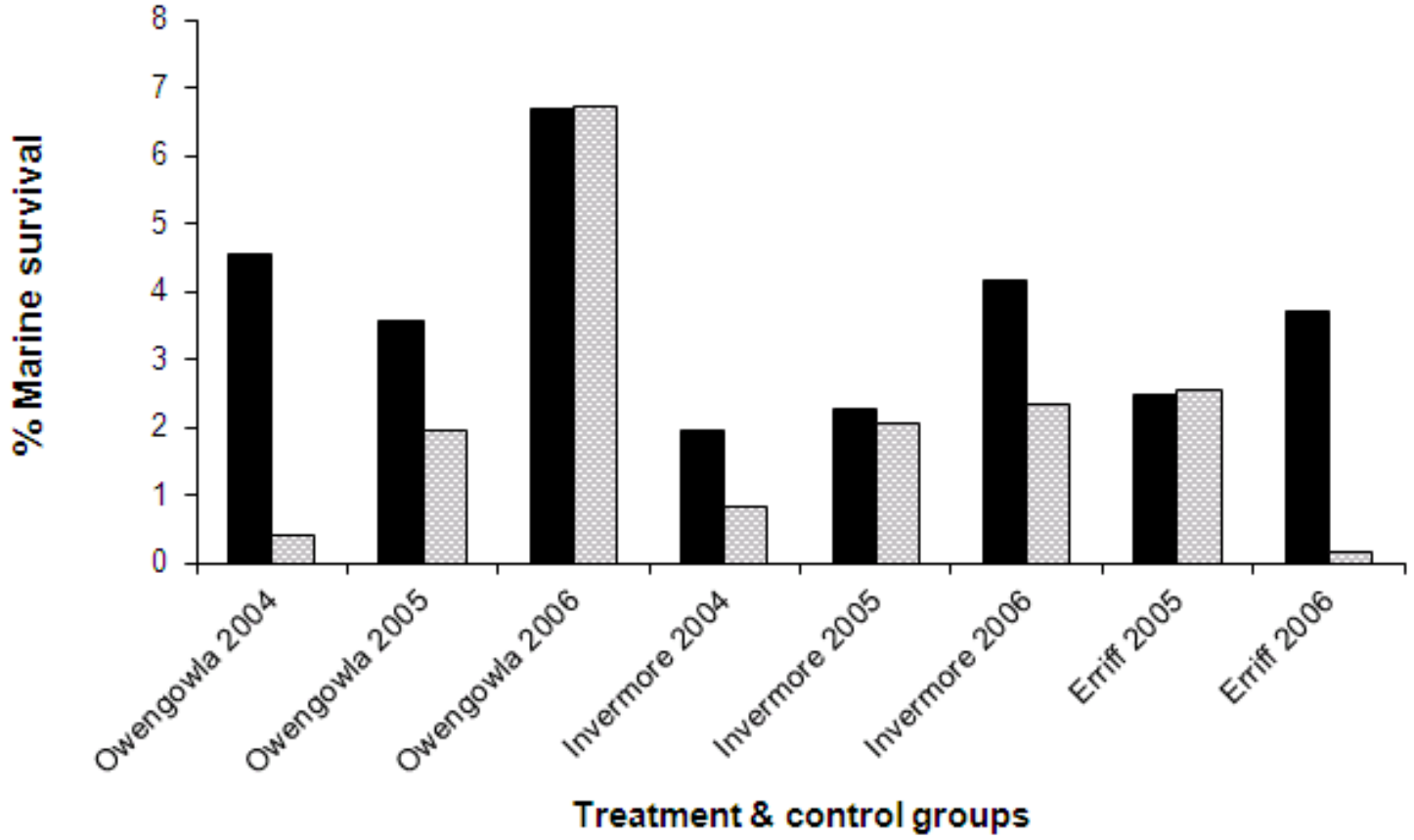
Inland Fisheries Ireland

Survival of Slice treated and control salmon

Release Location	Group	Fishery Year	Un-raised Return
Owengowla	Treated	2004	35
Owengowla	Control	2004	3
Owengowla	Treated	2005	51
Owengowla	Control	2005	22
Owengowla	Treated	2006	54
Owengowla	Control	2006	53
Invermore	Treated	2004	17
Invermore	Control	2004	9
Invermore	Treated	2005	37
Invermore	Control	2005	26
Invermore	Treated	2006	31
Invermore	Control	2006	17
Erriff	Treated	2005	44
Erriff	Control	2005	34
Erriff	Treated	2006	37
Erriff	Control	2006	2

Evidence for lice impact on salmon smolts

(Gargan et al. 2012. Can. J. Fish. Aqut. Sci.)



Impact of parasites on salmon recruitment in the Northeast Atlantic Ocean

Proc. Royal Soc. Krkosek et al 2012

- 2012 study, examined all Irish & Norwegian trials using salmon smolts treated & control fish for sea lice infection
- Results indicate a 39% loss of adult salmon recruitment due to sea lice infestation
- Lice acquired migrating through aquaculture areas

Potential for interaction of lice between farms and wild salmonids clearly exists

- Large body of evidence of ***potential for impact***
- Documented examples of impact on salmon, sea trout & char
- But evidence that an impact does not occur in all locations
- Impact may not occur in every year

- Lice may be at low levels on farms
- Weather conditions may reduce potential for impact
- Wind direction may affect dispersal of lice larvae
- Farm production strategy may lessen potential for impact

The Extent of any impact depends on;

- Location (long Norwegian fjords or short coastal bay)
- Production strategy (multiple sites, single generation sites, fallowing)
- Lice burden in spring
- Environment (salinity, freshwater influence, temperature etc)

- If a combination of circumstances exist, even in short coastal bays, there is potential for impact of lice from farms to impact out-migrating wild salmonids

Lessons learnt re ineffective lice control in Ireland

- Farm sites located too close to rivers
- Mixed year class production (Smolt & grower fish reared in close proximity)
- Rearing two sea winter fish with difficulty of controlling lice
- Protracted harvesting
- Lack of synchronised treatments
- Incomplete separation of generations and insufficient fallowing
- Fallowing not aligned with wild smolt runs

Lessons learnt re effective lice control

- Single generation sites, often in separate bays, (*sites one tidal excursion apart)*
- Fallowing before re-stocking; 4-6 weeks
- Whole bay spring fallowing
- Harvesting carried out remote from the grower sites.
- Annual synchronous "winter" lice treatment for all adjacent sites
- In Ireland, where there is a persistent problem with sea lice control, an incremental series of actions occurs;

Sea lice levels on Irish salmon farms

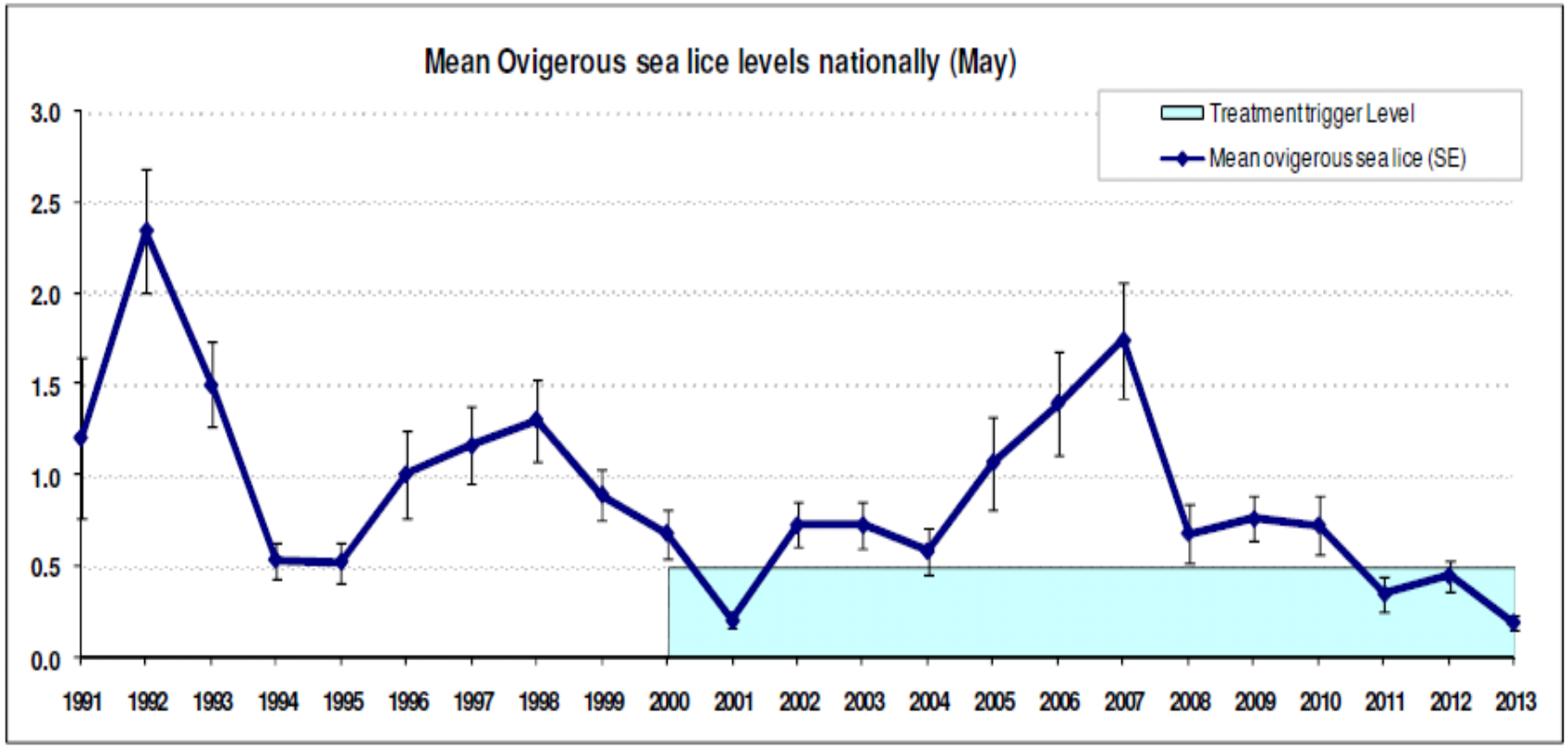


Figure 5. Annual trend (May mean) (SE) ovigerous *L. salmonis* on one-sea-winter salmon.

Future Prospects - Summary

- Expansion of salmon farming industry, new sites 15,000 tons
- New problems - Amoebic gill disease
- Resistance to available treatments
- Increasing mean sea temperatures
- Despite initiatives being pursued, there is likely to be negative interaction of sea lice between farmed and wild fish in some locations
- Likely to be need for “strategic initiatives” in particular areas where lice can not be controlled at sufficiently low levels

Possible Strategies to reduce sea lice impact

- Synchronized lice treatment over large areas
- Restricting production to a sustainable level
- Development of new lice treatments
- New production strategies
- Re-location of existing sites away from important rivers
- Move to land based farms
- Establish Marine Protected Areas
- Closed containment – Canada & Norway
- Possibility of new offshore technology

2007		*Lepeophtheirus salmo*		*Caligus Elongatus*	
		F + eggs	Total	F + eggs	Total
BEALACRAGHER BAY					
CURRAUN FISHERIES LTD					
Curraun					
Rainbow trout 2006 (I)		Harvested out			
Rainbow tr	1/17/2007	0.33	2.13	0.00	0.00
	2/13/2007	0.13	0.53	0.00	0.00
	3/1/2007	0.00	0.17	0.00	0.00
	3/22/2007	0.00	0.07	0.00	0.00
	4/4/2007	0.03	0.03	0.00	0.00
	4/20/2007	0.00	0.17	0.00	0.00
	5/3/2007	0.22	0.50	0.00	0.00
	5/16/2007	0.34	1.66	0.00	0.03
	6/7/2007	1.00	4.60	0.03	0.07
	7/11/2007	1.43	4.17	0.00	0.00
	8/14/2007	0.09	1.50	0.00	0.00
		Harvested out			
Rainbow tr	1/17/2007	0.00	1.33	0.00	0.00
	2/13/2007	0.00	0.03	0.00	0.00
	3/1/2007	0.00	0.03	0.00	0.00
	3/22/2007	0.00	0.00	0.00	0.00
	4/4/2007	0.00	0.00	0.00	0.00
	4/20/2007	0.00	0.21	0.00	0.00
	5/3/2007	0.00	0.12	0.00	0.00
	5/16/2007	0.06	0.22	0.00	0.00
	6/7/2007	0.25	3.19	0.00	0.00
	7/11/2007	0.26	1.67	0.00	0.00
	8/14/2007	0.13	0.83	0.00	0.00
	9/12/2007	0.47	2.00	0.00	0.00
	10/25/2007	3.41	10.93	0.00	0.00
		Harvested out			
Rainbow tr	4/20/2007	0.00	0.17	0.00	0.00
	5/3/2007	0.00	0.03	0.00	0.00
	5/16/2007	0.00	0.10	0.00	0.00
	6/7/2007	0.00	0.40	0.00	0.00
	7/11/2007	0.00	0.12	0.00	0.00
	8/14/2007	0.02	0.21	0.00	0.00
	9/12/2007	0.23	1.54	0.03	0.03
	10/25/2007	1.73	4.97	0.00	0.00
	11/15/2007	0.96	4.46	0.00	0.00

2008		*Lepeophtheirus salmo*		*Caligus Elongatus*	
		F + eggs	Total	F + eggs	Total
BEALACRAGHER BAY					
CURRAUN FISHERIES LTD					
Curraun					
Rainbow tr	1/15/2008	0.77	5.35	0.00	0.03
	2/6/2008	0.13	1.47	0.00	0.00
	3/6/2008	0.06	0.35	0.00	0.00
	3/20/2008	0.04	0.36	0.00	0.00
	4/3/2008	0.00	0.10	0.00	0.00
	4/17/2008	0.00	0.52	0.00	0.00
		Harvested out			
Rainbow tr	1/15/2008	0.17	4.00	0.00	0.00
	2/6/2008	0.15	0.59	0.00	0.00
	3/6/2008	0.04	0.41	0.00	0.00
	3/20/2008	0.00	0.07	0.00	0.00
	4/3/2008	0.00	0.06	0.00	0.00
	4/17/2008	0.03	0.27	0.00	0.00
	5/13/2008	0.06	0.84	0.00	0.00
	5/27/2008	0.10	0.70	0.00	0.00
	6/19/2008	1.60	3.50	0.00	0.00
	7/25/2008	0.57	3.13	0.00	0.00
	8/25/2008	9.00	29.11	0.00	0.00
	9/26/2008	21.63	62.31	0.00	0.00
	10/15/2008	1.28	3.86	0.00	0.00
Rainbow tr	5/13/2008	0.00	0.20	0.00	0.00
	5/27/2008	0.00	0.33	0.00	0.03
	6/19/2008	0.00	0.57	0.00	0.00
	7/25/2008	0.47	8.50	0.00	0.00
	8/25/2008	0.81	18.97	0.00	0.00
	9/26/2008	1.80	30.13	0.00	0.00
	10/15/2008	0.38	2.34	0.00	0.00
	11/20/2008	0.77	8.08	0.00	0.00
Rainbow T	11/20/2008	0.00	4.46	0.00	0.00

Potential Impact of Rainbow trout

- Some threat from sea lice transfer
- Escapes may be a more important threat

- Ecological effect
  - Loss of productivity
  - Predation
  - Direct disease transfer
  - Evidence in immune response gene (MHC)
  - Additional stress on vulnerable populations